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SYLLABUS

FOR

FIELD AND LABORATORY WORK

IN

DYNAMIC, STRUCTURAL AND PHYSIOGRAPHIC GEOLOGY

(Geology 1)

AT CORNELL UNIVERSITY

BY

RALPH S. TARR

ITHACA, N. Y.
A. WOODWARD STEPHENS
1902

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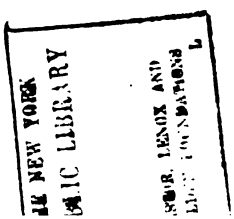


FIELD WORK.

GENERAL DIRECTIONS.—The students will provide themselves with the topographic sheets (Ithaca, Dryden, and Genoa sheets) mentioned under the various excursions and carry them on those excursions. They may be purchased for five cents each at the Coöperative Store or Taylor and Carpenter's. It is desirable, though not absolutely necessary, to have the following: A geological hammer; a bag for carrying specimens; a small pocket compass; and a pocket lens. Each student is expected to have a paper protractor in the note book.

The date of each excursion will be announced several days in advance on the Bulletin Board at the entrance to the Lecture Room. Most of the excursions are on foot; those to which there is expense attached are indicated.

Notes should be carefully made in the note book during each excursion. From these notes as a basis a carefully written report is required on each excursion. Each report must be handed in within a week of the day of the excursion. The reports are to be dropped in the box provided for that purpose in the Lecture Room. Reports handed in late will be received only when accompanied by an explanation given personally to the Instructor. The reports will be examined and returned within two weeks of the day of the excursion. Use paper (with or without covers) 5½ by 8½ inches. Do not fold. In addition to these reports the note books are to be handed in at the end of each term.

Specimens of each different kind of rock observed in the field are to be collected and these, together with those collected on Excursion VII, are to be brought into the Laboratory when called for, late in the first term or early in the second term.

In answer to frequent inquiries it may be stated that it has been necessary to make a general rule that no one excepting regularly registered students in this course will be allowed to go on the excursions.

EXCURSION I.—FALL CREEK.

STUDY OF EROSION, TRANSPORTATION, AND SEDIMENTATION.

Class will meet at Geological Lecture Room promptly at 2 o'clock.

(A) STREAM TRANSPORTATION: Is the stream carrying sediment? Will the amount of sediment be the same at all times? When will it be greatest? Why? How does the current move the large fragments? The small fragments? Why are the larger fragments rounded? Is the stream cutting into the banks? What takes place opposite these places of rapid erosion? Materials picked up by the stream are transported toward its mouth; are they apt to be dropped before reaching the outlet of the stream? Where? Will they be taken up again?

(B) MEANDERING: Are there any abandoned channels? What causes the stream to change its [illegible]t is the origin of the small islands? Notice wh[illegible] is flowing against rock. Is erosion as rapid the[illegible]ft?

(C) DEPOSIT AND STRATIFICATI[illegible]terials here show any definite arrangement? Ho[illegible] deposit be formed? What is stratification? Explain its origin.

(D) DIFFERENCE IN WORK OF EROSION: Why is the valley narrower in the rock than above? Can you find evidence that even here the stream is receiving sediment for transportation? How is it obtaining it?

(E) DEPOSIT IN QUIET WATER: Notice the small island at the upper end of Beebe Lake. Could it have been formed by the stream? If so, are the materials stratified? Why is it not farther up stream? Given time, what effect will this deposit have on the lake? Are streams that enter Cayuga Lake having a similar effect.

SUPPLEMENTARY: Notice the ripple marks; the joint planes; the glacial scratches on the rock; the difference in the width of the valley when in rock and in drift. Take and record the compass direction of the joint planes; of the glacial scratches. Later excursions will consider these phenomena.

... the muddiness of water shows presence of sediment. The amount of sediment varies being greatest where the streams velocity is greatest because there its carrying power is greatest. To double the velocity of the stream is to increase its carrying power to the 6th power of 2 or 64. To reduce the velocity ½ is to reduce the carrying power $\frac{63}{64}$. The current moves the large fragments by rolling or dragging; at times, the ice pushes against the fragments or heaps them up & so carries them along. The small fragments are carried in suspension (Some chemicals in solution) The larger fragments are rounded by rolling and rubbing. The stream is cutting and undercutting its banks. Opposite a place of erosion is usually a shoal or deposit of debris. Materials in transportation are dropped in shoals & taken by the way, especially the larger [illegible] in course of time

recent channel
ut its way. Obtai
inding on rock + from
Yes. It is at end of cu
eam does its greates
. Yes.
entary.
marks are marks of w
which in time were h
Joint planes are cle
im top to bottom. Th
ten cross at right angle
along these breaks

SUMMARY: Rivers erode by vertical cutting and by swinging, or meandering. Materials are also supplied by weathering. All these materials are borne downstream, some, especially the coarser, halting on the way. They are assorted and, when deposited, are thus arranged in layers. Conditions in rock and unconsolidated drift are similar, though the amount of work performed differs greatly. In time stream deposits fill lakes.

NOTE. In report, show clearly in what ways the river obtains sediment; how it is transported; and the manner in which it is deposited. Illustrate these points by specific instances observed on the excursion.

REFERENCES. Tarr's Elementary Geology, pp. 151–165; 174–175; and 73–77. Geikie's Text book, pp. 180–189; 498–501; and 379–389.

EXCURSION II.—ITHACA FALLS.

A STUDY OF STRATIFICATION, EROSION AND DENUDATION.

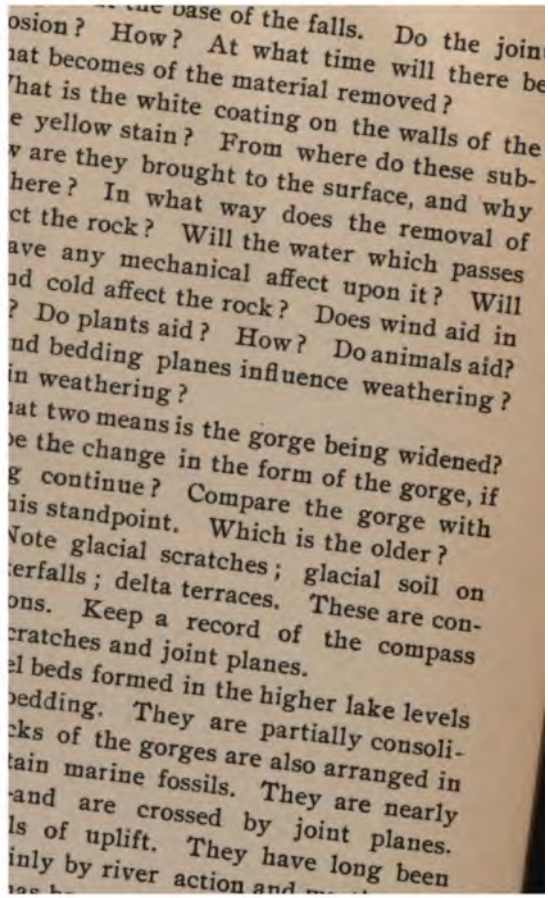
The class will meet in Geological Lecture Room at 2 o'clock.

(A) GRAVEL BANK: *Stratification and Consolidation:* What materials do you find here? Are they assorted? Do you see any layers which seem to be made up of thin leaves—laminae? Such a deposit is said to be stratified, or bedded, and the layers are called strata, or beds. Are any of the beds very thick—massive? Are the layers horizontal? The condition of stratification observed here is known as current, or cross, bedding. What is the white coating on some of the pebbles? What effect is this white deposit having on the gravel? What effect has the weather on the gravel slopes? These gravel beds were formed as deltas in a higher level of Cayuga Lake.

(B) GORGE: *Stratification of the Bed Rock:* Of what are the rocks composed? Are they stratified? Is there any variation in the strata? Explain. What are the names applied to these rocks? Do the strata on the two sides of the gorge match? Are the strata horizontal? Do you find cross bedding? What does this fact signify? Find fossils in the rocks. How did they get there? Why are they more abundant in some layers than in others? What is the geological age of these strata?

Erosion: What evidence is there of erosion? Explain pot

[redacted]


base of the falls. Do the join
osion? How? At what time will there be
nat becomes of the material removed?
What is the white coating on the walls of the
e yellow stain? From where do these sub-
v are they brought to the surface, and why
here? In what way does the removal of
ct the rock? Will the water which passes
ave any mechanical affect upon it? Will
nd cold affect the rock? Does wind aid in
? Do plants aid? How? Do animals aid?
nd bedding planes influence weathering?
in weathering?
nat two means is the gorge being widened?
e the change in the form of the gorge, if
g continue? Compare the gorge with
nis standpoint. Which is the older?
Note glacial scratches; glacial soil on
erfalls; delta terraces. These are con-
ons. Keep a record of the compass
cratches and joint planes.
el beds formed in the higher lake levels
edding. They are partially consoli-
cks of the gorges are also arranged in
tain marine fossils. They are nearly
and are crossed by joint planes.
ls of uplift. They have long been
inly by river action and

[redacted]

EXCURSION III.—ALONG LAKE SHORE TOWARDS ESTY'S GLEN.

A STUDY OF LAKE DEPOSIT, STRATIFICATION AND JOINT PLANES.

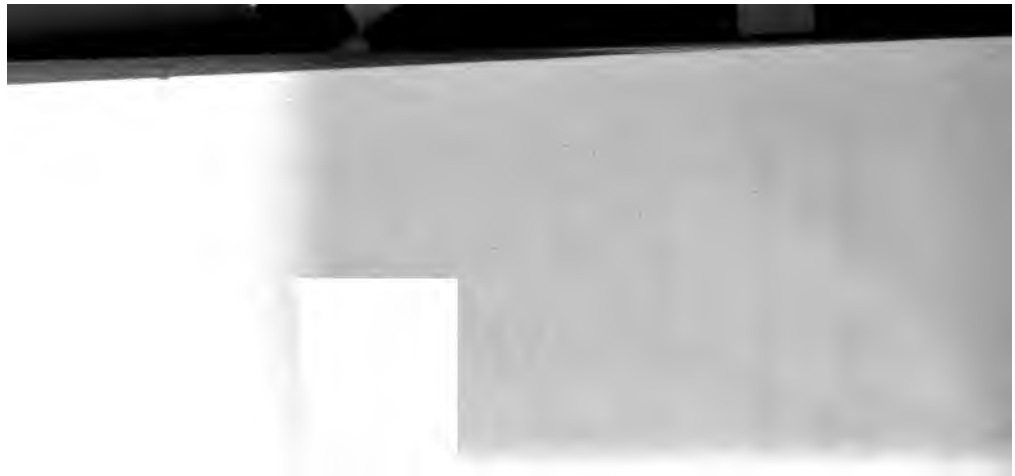
Meet at Renwick Park at 2:30.

(A) LAKE DEPOSITS AT PIER: Why is the lake so shallow here? What is the nature of the material? In what two ways is the vegetation helping to fill the lake? Notice ripple marks beside the pier. Explain their formation. Have you seen similar markings on the shales? What does that show as to the depth of water in which the shales were formed? How were the marks preserved?

(B) DELTAS: Notice the deltas opposite all the streams. On which side of these deltas are the streams found? Why on that side? Of what materials are the deltas composed? Compare with the materials in the gravel bank near Fall Creek. Compare with the materials at Renwick. Why is there no clay? Where does it go? Will it be stratified? Why is there no sand? Why are the tops of these deltas so high above lake level? Do you know whether the present lake level is always maintained? If not, why should it vary? Why do the streams disappear in their lower course?

(C) WEATHERING: Look for deposits of alum. Explain their origin. Notice the talus at the foot of the cliff. What is its origin? Sometimes it assumes the shape of the segment of a cone; and it is then called a talus cone. Find examples. What influence does the weathering of a shore cliff have on sedimentation?

(D) STRATIFICATION: Make observations on the stratification of the shale beds. What difference in the layers do you observe? What resemblance do these beds bear to the deposits being made in the lake? What differences? Make the same comparisons with the stream deposits previously studied. Observe the dip of the strata and measure it with your protractor. Keep a record. How does the dip compare with that in Fall Creek Gorge? Why this difference?



(E) JOINT PLANES: Examine the joint planes carefully. Note their direction. Compare with direction of joint planes observed on previous excursions. Why are they so regular? Are there any layers which some of the joint planes fail to cross? Why should the cliffs on the east be higher than those on the west side of the lake? What influence have the joint planes had on coast form?

SUMMARY: The lake is being filled with sediment brought in by streams, rain wash, wind, and waves, and the filling is aided by vegetation. The materials are being assorted and arranged in layers. Assortment is also seen in the shale strata that were formed in the shallow, ancient Devonian sea. These strata have been given a dip at this point; and they are jointed.

NOTE: The report should contain a clear statement of the causes tending toward lake filling, and the results in the way of assortment of materials and the formation of strata. There should be a statement of the conditions revealed by the shale cliffs, indicating stratification and later tilting and jointing. The influence of the joint planes should also be stated. Draw illustrations from features observed on the excursion.

REFERENCES. Tarr's Geology, pp. 176–193; 277–282; Geikie's Text Book, pp. 397–400; 523–533.

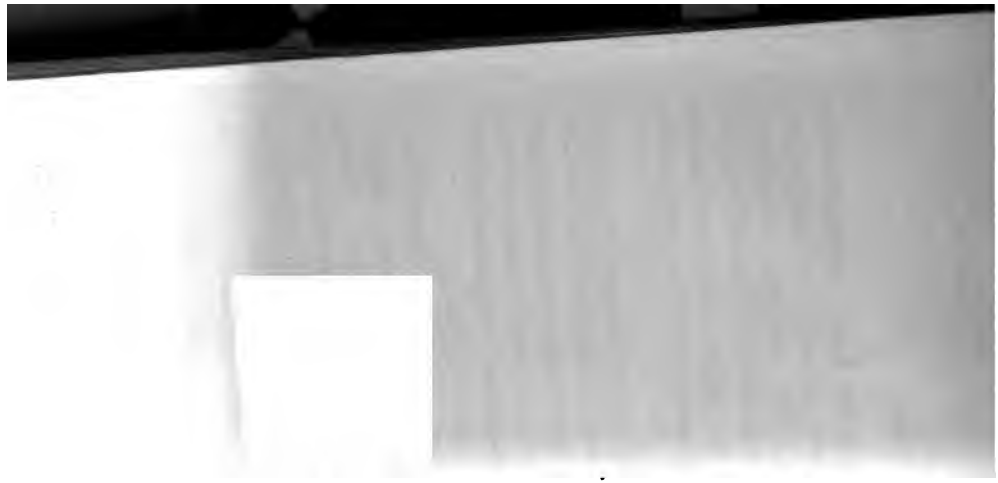
EXCURSION IV.—TO TAUGHANNOCK.

June 15, Prof. Brigham.

A GENERAL VIEW OF THE GEOLOGY OF THE ITHACA REGION AND A CORRELATION OF PREVIOUS OBSERVATIONS.

Excursion by steamer all day Saturday. This excursion will excuse the students from two of the laboratory periods at the end of the first term. Take *Ithaca* and *Genoa* topographic sheets. Expense $.25 to $.35. Meet at steamboat landing—near Lehigh Valley Station—at 8.30 A.M. Collect and preserve, for study in the laboratory, specimens of the various rocks studied.

(A) PASSING DOWN THE INLET: Notice that it winds along through a level, swampy plain. At the salt well it is 420 feet through loose unconsolidated material to the rock of the valley bottom. Explain the origin of this plain and how its surface comes to be above present water level. Is it ever flooded? In



~~4. When lake was at higher level this deposit made in st at mouth of Cayuga Inlet.~~

9. This plain is a flood plain of Cayuga Inlet
rmed of deposit continually brought down,
ut in greater quantities in flood time
hen the stream built it up above its
rm normal level. Along the bank of the
stream is a ridge of material, the larger
fragments that are first dropped, and
back of this are marshes. It is yet often
flooded and so sometimes to go over.
Rank vegetation binds the deposit together.
Piers or breakwaters are run out into lake
to confine and deepen the inlet. The
water is shallow beyond because of deposit
under water at mouth of stream.

B. The cliff

The rocks are inclined to the south about 100
ft. to 1 mile. Dip is slight departure from the hori-
zontal of a strata or series of strata.

Strike

C. Genesee shales are blackish and in very thin beds
Quantities of fossils found in it.

Outcrop is appearance at surface.
Outcrop of Tully limestone is
very thick beds - it is much harder
than shale because it resists weather
more than shale does. It dips toward
south. You can see this lime stone
on west shore farther north than
East shore.
Hamilton group is lime and shale.

case it is, what happens? What effect on this plain does the rank vegetation have? Why are piers built at the entrance into the lake? The water of the lake is shallow for a mile from the lighthouse; why?

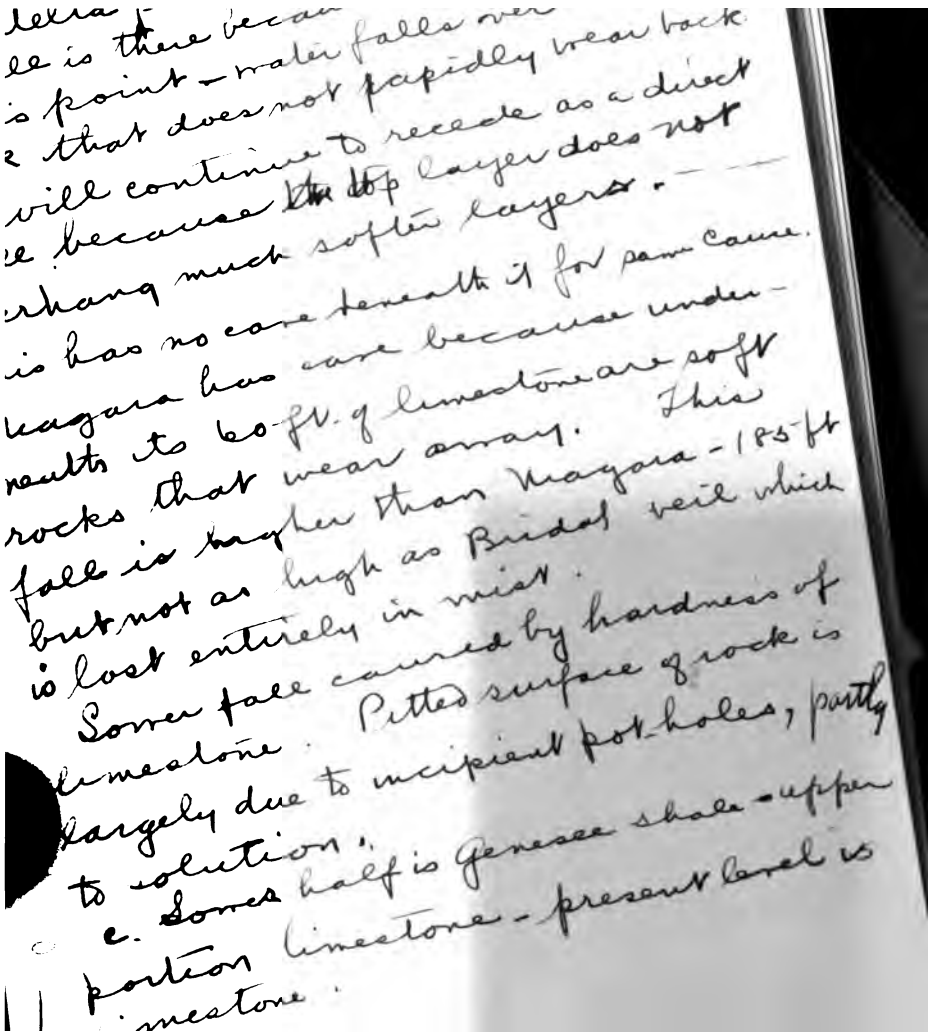
(B) THE LAKE SHORE: Notice that this consists of a rock cliff with a beach at the base. What is the cause of this cliff? Are the rocks horizontal or inclined? If inclined, in what direction and how much? What is *dip*? What is *strike*? These rocks are shales with thin-bedded sandstones. They belong to the *Ithaca group* of the *Portage* division of the *Devonian* rocks (pp. 86 and 87). Do the rocks on the east shore of the lake seem to be of the same kind?

(C) FIRST LANDING, just south of Glenwood. Here is the line of parting between the *Portage* and the *Genesee* shales? Do you notice any differences between these two formations; if so what? Are there any fossils in the Genesee? The Genesee is a typical shale separated into thin sheets along planes of weakness, known as *bedding planes*? What causes these bedding planes?

(D) GLENWOOD POINT is made of shale gravel. Explain its formation at this particular point. Notice the peculiarities of its position with reference to Glenwood Creek. Find examples of similar points during the day.

(E) BEYOND GLENWOOD, to the north, is the outcrop (what is an *outcrop*?) of a thick bedded limestone, known as the *Tully*. Is this in layers or in one sheet? Is it harder than the shale? How can you tell? Is it horizontal or dipping? If the latter, in what direction? Can you see this limestone on the opposite shore? Was it once continuous? The rock below the Tully is the *Hamilton*. Is it limestone, sandstone or shale?

(F) STOP AT PROFESSOR BAILEY'S WHARF: The rocks at this point are Hamilton. Do you find any fossils; if so what kinds? Notice oxide of iron and white deposits of alum. How do they originate? Notice also certain rounded masses imbedded in the rock; these are *concretions*. How did they get there? Are they stratified like the shales? Professor Bailey's house is built of Tully limestone, which outcrops here. See if you can find any fossils in this rock. Notice how high the Tully is above lake level. Notice the texture of the Tully; is it hard or soft?



Why is it called limestone, and where did the material come from?

(G) CROW-BAR POINT: In what direction does it extend? Explain the reason for this. Beyond Crow-bar Point notice the rocks; do they dip? If so, in what direction? Notice on the east shore the large, broad valley of Salmon Creek. The Tully outcrops at Ludlowville in this valley, there causing a fall.

(H) TAUGHANNOCK: (*a*) What is the cause of the level point which extends into the lake?

(*b*) South of Taughannock is a fall over the Tully. Why is it there? Examine it to understand this cause for falls. What will be the future of this fall? Compare with Niagara. In the gorge there is another low fall; what causes it? Do you recognize the hard rock at its brink and above it. Notice the pitted surface of the hard rock forming the brink of the falls; explain this feature.

(*c*) What kind of rock composes the walls of the gorge? Explain the black color of the shales in the gorge. Notice evidences of weathering. Notice alum on the rocks; also the imbedded concretions. Where does the alum come from? Observe the compass direction of the joint planes. How do they compare with previous observations?

(*d*) What causes the fall to be so high? Do you see the top of the Genesee? Figuring from the dip and the distance between here and Glenwood, at what level would you expect to find it? Explain the contracting of the gorge above the falls. About ten years ago the rocks at the crest of Taughannock formed an angle of ninety degrees, pointing downstream. It is now a re-entrant angle. What could cause such a change, and what effect do such changes have on the gorge? Notice that the water falls so far that much of it reaches the bottom in spray. What effect does this have on the weathering of the rocks? Do you suppose the agencies of denudation are most active in summer or in winter? What differences are there in the forces operating in these two seasons? Why is the pool at the base of the falls so deep? Why is there an accumulation of fragments just in front of this pool instead of a deep channel leading away from the fall? Is erosion or weathering accomplishing the greatest work of denudation?

d. Height of fall largely determined by hardness of the rock which is not easily cut into.

The narrowness of gorge above falls is due to straight confined course of stream.

Change in angle is probably due to cleavage of a column formed by four joint plains: 1. 2. This Concentrates stream in angle rather than causing it to spread widely. Spray aids greatly in weathering of any rocks. Agents of de-

(e) Compare this gorge with that of
resemblances. What differences do yo
(f) Note the small *dikes*. What are
presence here signify? Do you know o
(I) BEYOND TAUGHANNOCK: Wh
noticed? What about the dip of the ro
cline? A *syncline*? A *monocline*? How ar
relation do the foldings of strata bear
planes? With the lake as a base line, d
the low anticline and syncline on the ea
for the west shore. Compare the two.
tinuous? If so, explain the removal of t
(J) LUDLOWVILLE DELTA: What is t
Examine the gravel bank back of the salt w
topped? What is the origin of this deposit
similar deposits? What does its presence
ing the former level of Lake Cayuga? Re
later excursions. It is 1500 feet to salt at
at Ithaca (seven miles distant); and the
Syracuse (about fifty miles to the north of
direction and average amount of dip of the
you expect the same dip for the rocks above
ville wells pass through the Tully limest
Ithaca? In what direction would we go to fi
strata lying below the Tully? Are the rocks
lowville above or below the Tully?
(K) ALONG THE EAST SHORE: Compa
shore in detail.

SUMMARY AND GENERALIZATION: Cayuga
river valley formed by a stream which flowed
stream, cutting down, has revealed the unde
strata and has cut across a series of gently fold
valley has been greatly broadened by long den
has separated once continuous layers by remov
parts. The valley was later widened and deep
rosion; and a lake was formed in the basin behin
northern end. The lake

The stream seen here [illegible] The higher
vout 100 acres here. The higher
nd a terrace is a delta formed
en level of lake was higher

streams; and, given time, it will disappear, being replaced by a broad plain already begun at several points.

An important effect of the glacier has been to turn tributary streams aside from their former valleys so that, being young, they are narrow gorges, with many falls and rapids, because the time since the ice melted away has not been long enough for the streams to cut their valleys down to lake level. The work of these streams has been retarded here and there by hard layers which have caused falls.

NOTE. In your report tell briefly what you have observed under each heading. Then write a summary, of not over two pages, giving the history of this valley as revealed by the facts observed on the excursion. Formulate this summary from your own notes, not from the summary in the syllabus.

REFERENCES. Tarr, Elementary Geology, pp. 283–284 and 346–347. Geikie, pp. 531–534, 538 and 582. Also Tarr's Physical Geography of New York State, Chapter V.

EXCURSION V.--THE TERMINAL MORAINE.

TO STUDY GLACIAL DEPOSITS.

Class meets at the E. C. & N. Station at 2:20. Take *Ithaca* and *Dryden* sheets.

(A) Recall previous observations on glacial scratches. What were their directions? What besides glaciers could account for these scratches? What facts are there showing that these causes have not been of importance?

(B) RAILWAY CUT NEAR STATION: Of what is it composed? Contrast with the cut previously seen in the gravel pit. What resemblances between the two? The material in this railway cut is called *till* or *boulder clay*. Why the latter? How could the material of the gravel pits be made from till? Where would the clay go? Till is a glacial deposit. What evidences of glacial origin can you find? Why are glacial deposits not assorted and stratified like those made by water?

(C) THE MORAINE: When a glacier front remains in one

moraine. Would it be stratified or unstratified? Why? What causes can you suggest for the fact that the form is very irregular and the composition variable?

Such a moraine was formed in Cayuga valley. Trace the ice front on the maps, on the basis of information supplied by the Instructor. Why should it extend so far southward in the Cayuga valley? While the moraine where you stand is not very pronounced, not much more than a mile in width, that in the valley south of Ithaca is about twenty miles from north to south, and very finely developed; why should it be so much more pronounced in the Inlet valley? How does that compare with the idea that the Cayuga valley has been markedly deepened and broadened by ice erosion?

(D) SIX MILE CREEK NEAR MILL: *Examination, comparison and contrast of the deposits of drift.* First make careful observations of materials, texture, and arrangement of the two classes of drift. Account for the assortment of materials in the one case. What is the origin of the unassorted deposit? Are there foreign fragments? Bring forward all the evidences of glacial origin supplied by the till bank. What facts are there against considering it to be due to decomposition of the rock, *i.e.* to its being classed as a *residual soil?* What facts are there in favor of believing it to have been brought there by some agency, *i.e.* to be due to *transportation.* Can it be due to rivers? to icebergs? to wind? There are objections to each of these hypotheses. Are there any facts opposed to glacial origin? Does the moraine itself suggest glacial origin? Could a morainic band be formed by water? Could it be formed by water with icebergs, as once suggested?

(D) RIDGE ABOVE THE MILL: What is this material? Account for the vertical cracks. Is there any sand? How could the layers be so crumpled? Note the upper part of the cut. Does the material differ from that beneath? Why is its color different? What is its origin?

SUMMARY: A moraine, marking an ice halt, crosses the Finger Lake region. Its form is irregular and its composition variable. Melting of the ice furnished water in which some of the materials were assorted; and in lakes, held up by ice dams,

deposits of stratified materials, both fine and coarse grained, were made. The deposits made directly from the ice are unassorted, and the materials could have been deposited only by ice.

NOTE. In report present a clear statement of the evidence of glacial invasion of this section and show that ice alone accounts for the facts. Also show how the presence of assorted materials deposited by water harmonizes with this conclusion.

REFERENCES. Tarr's Geology, pp. 195; 213–216. Geikie, 417–427. Tarr's Physical Geography of New York State. Chapter IV.

EXCURSION VI.—THE BANKS OF FALL CREEK.

A STUDY OF ELEVATED DELTAS.

Meet at Lecture Room at 2 o'clock. Take *Ithaca* and *Genoa* sheets.

(A) *Examine the terraces* at Cornell Heights, noting their form and reading their elevation with Aneroid barometer (Explain Aneroid). Also use Locke Level. Are these deposits stratified or unstratified?

(B) *Cross gorge to south side.* Examine terraces here in same way. Compare with Ludlowville terrace (p. 31). Locate (on maps) similar terraces at the mouths of the other streams.

(C) *Origin of Deltas.* What could cause such deposits here? Compare form and composition with deltas forming at present, previously studied. These terraces have all the characteristics of deltas. Name these characteristics. How could deltas be formed in these situations? Consideration of their origin.

(D) *Springs.* Why should there be a *spring* here? What is the source of the water? Why does it come to the surface at this point? Consideration of the causes of springs.

(E) *Examine cut opposite Percy Field.* (*a*) Explain assortment. Explain the cross bedding (also called *current bedding*). Such bedding is characteristic of rapid currents changing in velocity and direction—as on coast lines and in rivers. Cross bedding is also present in wind-made deposits. How do you know that these are not wind deposits? (*b*) Examine the pebbles. Do you find glacial scratches on them? Why? Explain their rounded form. Why are there so many different kinds of rock

among the pebbles? (*c*) Find some of the pebbles cemented together. What is the cement? What is its source? Why are some of the layers cemented, others not? (*d*) Fine stratified clay is found beneath these gravels. What is its origin?

SUMMARY: At a higher level of Cayuga Lake, held up by an ice dam, deltas were built opposite the mouths of the creeks at these levels. The higher levels were determined by the outflow channels along the ice margin. The materials of the deltas were assorted and deposited in rapidly moving currents.

NOTE. Write a report stating clearly the characteristics of the deltas and the reasons for their occurrence in these positions.

REFERENCES. Tarr's Geology, pp. 356–360. Tarr's Physical Geography of New York State, pp. 255–265.

EXCURSION VII.—INDIVIDUAL EXCURSION.

THE COLLECTION OF ROCKS.

Each member of the class will go to the gravel bank near Percy Field and collect a dozen different kinds of rock. These, added to those collected on previous excursions, will be brought to the laboratory (later when called for) and identified. A regular period will be allowed for this excursion, but students may go at any other time. Failure to have the specimens when called for will be considered a cut.

EXCURSION VIII.—CASCADILLA VALLEY.

A STUDY OF THE GLACIAL AND PREGLACIAL HISTORY OF THE VALLEY.

Trip by wagon, cost about $ .75. Class meets at the Geological Laboratory promptly at 2 o'clock. Seats will be provided for all regular members of each section. Students who are unable to go, or who wish to change sections, must notify the instructor or else pay for the seat reserved. Take *Dryden* sheet.

(*a*) VALLEY FORM: Note the Cascadilla gorge. What is its form? How does this form vary as you proceed up the valley? What effect has the discovery of rock by the stream had on the form of the valley? Is the stream obtaining materials for transportation? Give instances. Why is there no rock in the middle section of the stream course?

(B) MORAINE: The broad moraine, previously studied, is remarkably level where crossed, though, even here, its surface is ridged. Its depth is known to be over 130 feet. Note the fine-textured clay in the fields. How can this be accounted for?

(C) ICE LOBES: A tongue of ice, extending up Cascadilla, formed a *lobate moraine*. What is a lobate moraine? Examine this and state its characteristics. Why should the ice front be lobate here? Will it probably be found to be so in other valleys?

(D) ALLUVIAL FANS, LATERAL MORAINES, ETC.: Note the broad alluvial fans on the north side of the valley. Ice tongues once extended over the sags in the Turkey Hill range, building moraines and eskers; and the outwash from these ice tongues has formed these alluvial fans. State their characteristics. There is a lateral moraine on the valley side. Note its characteristics, especially on the east side of the tributary valleys. Why there? On the map draw the ice front in Cascadilla valley as it took different positions during the retreat of the ice. Was there a marginal lake in front of this lobe? Where would such a lake outflow?

(E) FROM THE TOP OF EAGLE HILL: The rocks of the hill-tops are Upper Devonian shales with many sandy layers. They have been exposed to denudation continuously, in all probabil-

into Six Mile Creek. Examine this overflow channel and state its characteristics. What other overflow channels have you previously been told about?

SUMMARY: The ice once occupied all of Cascadilla valley and covered the hill tops. It then melted back and took a stand across the Finger Lake region. The history of its withdrawal is written in records of glacial deposits,—moraines, eskers, wash plains, etc. Lakes were formed and their levels changed frequently. From the hilltops we see a record of great denudation.

NOTE. In your report state clearly the evidence of great denudation. Also, state the history of the ice withdrawal from this land, and the influence of valleys on the form of the ice front. Draw illustrations from your observations on this excursion.

EXCURSION IX.—SIX MILE CREEK.

STUDY OF THE VALLEY FORMS.

Class will meet at 2:20 at the South Hill Bridge, which crosses Six Mile Creek near the south end of Stewart Avenue. Take *Dryden* sheet.

(A) *Note the breadth of the valley where the bridge crosses it.* Measure its approximate width. Is there rock in the bottom? Why? Is the stream now cutting this gorge? When then was it formed?

(B) *Measure the width of the valley at the Mill.* Is the stream now cutting this gorge? Why is there the difference in width of the two parts of the gorge?

(C) *Passing up the valley*, note the expansion and contraction of the gorge, *i. e.* narrow rock-cut gorges and broad amphitheatres. What is the explanation? (*a*) First examine the walls of one of these amphitheatres. Of what are they made? This tells why the valley is broad here; but why is there no rock in certain parts of the boundaries of the amphitheatres, while there is rock in the narrow gorges? (*b*) Return to the bridge by the Mill. Note the moraine pile previously examined (Excursion VI.). It stands as a high wall in the broad, gorge-like valley. This (interglacial?) gorge is buried here so that the stream does not occupy it; but both above and below this point the

stream is in the buried gorge. What is an interglacial gorge? Where the stream crosses from one wall to the other of the buried gorge there are amphitheatres. Elsewhere the stream is cutting narrow gorges in the banks of the buried valley. Make a drawing to show these facts. In it show the three parts of the valley at the Mill, (1) the broad, preglacial valley, (2) the buried gorge, and (3) the postglacial gorge. Consideration of the question whether these are interglacial or preglacial gorges.

(D) *Contrast the width of the buried and the postglacial gorges.* Why this difference? Why are the rock gorges narrower than the amphitheatres? What relation have meandering of streams and landslides to the question? What causes the landslides?

(E) What *causes for waterfalls* have you seen so far on this and other excursions?

SUMMARY: Either preglacially or interglacially—the exact time is not yet positively known—the streams were given power to cut gorges in the bottoms of the broad, mature preglacial valleys. These gorges were buried beneath drift, especially on the line of moraine, and the postglacial streams have only partly rediscovered these old gorges. Where they have found them they are flowing in broad amphitheatres. Elsewhere they are flowing in narrow gorges cut in the old valley walls; and the hard work thus imposed on the streams has resulted in the formation of waterfalls.

NOTE. In your report state the evidences that you have seen of buried gorges, and the influence of these and drift deposits on the valleys near the campus. Also make a statement of the causes of waterfalls.

REFERENCE. Tarr's Physical Geography of New York State, Chapter V.

EXCURSION X.—TO NEWFIELD.

A FURTHER STUDY OF MORAINES.

The class will meet at The Corner Bookstore (State St. corner of Tioga) promptly at the laboratory hour. Seats will be provided in the wagons for all regular members of the class. Therefore, anyone wishing to change, or who is unable to go, must notify the instructor, so that no more seats than are necessary need be provided. Otherwise the student will be expected to pay for the seat reserved. Expense about $.75. Take *Ithaca* sheet.

[redacted]

(A) ITHACA TO BUTTERMILK: Note the level delta. Why does the Inlet meander so? Why is its current so slow? What causes the frequent elevations along the small streams on the way to Buttermilk? Notice where the level delta merges into the moraine which fills the valley bottom as far as Spencer Summit. Notice the buried gorges of Buttermilk and Coy Glen; also notice the elevated delta terraces.

(B) KETTLE HOLES: Moraines have numerous kettle shaped depressions, often containing water. What two reasons can you suggest for the absence of water from some? There are scores of such kettles in this moraine. Suggest explanations for them.

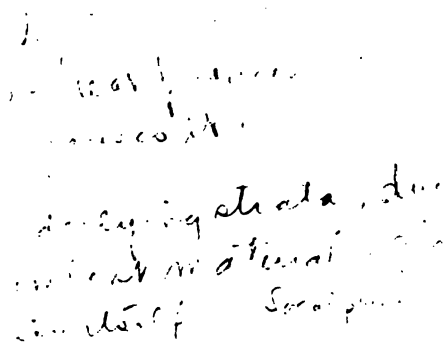
(C) LICK BROOK: Notice the nature of the stream course and deposit outside of the gorge. Where is the water? Find evidences of chemical action on the valley wall. What is the nature of deposit of calcareous tufa here?

(D) NEWFIELD CLAY PIT: Is it stratified? How may it have been formed? What has caused crumpling of layers? Why have not the pebbles lost their striations? How could such large deposits be brought to their position in this fine clay deposit? There are other clay deposits near by. Why is the clay yellow above and blue below? How does this clay differ from residual clay produced by the decomposition of rock in place?

(E) EXAMINATION OF SOME OF THE NEARBY MORAINE TOPOGRAPHY. Refer back to observations made and conclusions reached on previous excursions. This is a part of the great belt of moraine reaching far to the west and east. This moraine marks a halt in the ice as it withdrew, a *moraine of recession*. There are others to the north. At the point of farthest advance the ice reached well into Pennsylvania. Is the moraine here an indication of a lobate ice front, as in Cascadilla Creek?

SUMMARY: The delta of the Inlet is elevated near the margin by alluvial fans. Out of it rise moraine hummocks, a part of the great terminal moraine of the Finger Lake region. This moraine is irregular in form and texture, as well-defined moraines always are.

NOTE. Write a report of this trip section by section. Then make a summary statement of what you have learned on this and other excursions regarding the moraine and the position of the ice front. Tarr's Physical Geography of New York State, Chapter IV.



EXCURSION XI.—UNION SPRINGS.

A STUDY OF THE LOWER DEVONIAN AND UPPER SILURIAN STRATA.

By train and wagon, all day Saturday. Two laboratory periods are allowed for this excursion, to be provided for at end of term. Take *Genoa* and *Auburn* sheets. Expense about $1.90.

(A) THE TRAIN PASSES ALONG THE LAKE SHORE. Notice the high cliffs; also the frequent forelands. What is the origin of the latter? The rocks of the lake shore cliffs are *Lower Devonian* shales. Note the *Marcellus* shales (pp. 86 and 87). What other shales do they resemble in color and texture?

(B) FIRST QUARRY. (*a*) What differences do you note in the layers? The black fissile shales in the upper portion of the quarry represent the beginning of the overlying Marcellus shales. What then is the name of the limestone? What is the meaning of the name? (*b*) Find fossils in the black shale. Do you find any minerals in this shale? How can you explain the alternating thin bands of shale and limestone? Why should limestone be formed at one time, and then, above (or below) it, shale? (*c*) What about the dip of the rocks in this quarry? Take the angle and direction of dip at several points.

(C) SECOND QUARRY. (*a*) How does the dip of the strata compare with that in the first quarry? This is the same limestone as in the last quarry. Which is the higher? (*b*) Are the layers in this quarry strictly continuous in east and west direction? If not, what is the cause of their interruption? Such a break in the continuity of sedimentary layers is caused by faulting, and the resulting break is known as a *fault*. What type of fault is seen here? The angle which the line of breakage makes with the vertical is known as the *angle of hade*. What is a fault breccia? If you find such a break, take the approximate angle of the hade. (*c*) On the blocks removed by the quarrymen notice

(D) CONSIDERATION OF VARIOUS THEORIES FOR ORIGIN OF THESE FOLDS, SLICKENSIDES, ETC.: Mountain folding, solution of salt, formation of gypsum.

(E) ORISKANY. The next point visited is the *outcrop of the Oriskany sandstone*, northeast of Union Springs. (*a*) This sandstone lies at the bottom of the Devonian system. Of what are the sand grains composed; and what cements them together? Why are they so loosely cemented in comparison with other sandstones? (*b*) Most of the fossils in this rock are represented by casts. What has become of the carbonate of lime with which they were once filled? (*c*) This formation varies in thickness, and is absent in some parts of New York. What do you consider to be the origin of such a deposit? (*d*) The names of some of the typical distinctive fossils are *Hipparionyx proximus*, *Spirifer arenosus*, *Rensselaeria ovoides* (see Dana's Manual, pp. 577–579). (*e*) Underlying this sandstone notice the hard limestone rock of the *Helderberg*. The two formations are unconformable. What is an *unconformity*? Find fossils in the Helderberg, especially Tentaculites.

(F) NEXT VISIT THE GYPSUM QUARRIES, just north of Union Springs. What age are these rocks? How do you account for the origin of the gypsum? How does gypsum differ from calcite in hardness and other physical properties? Find selenite veins in the gypsum rock. Do you see any evidences of water action on these rocks? Some feet below these gypsum beds are the salt beds. What do you notice regarding the soil covering of the gypsum?

Uses of gypsum:—plaster of Paris, land plaster (fertilizer), food adulterant, kalsomine and crayons.

(G) COLLECT AND PRESERVE FOR FUTURE STUDY specimens of Marcellus shale; Corniferous limestone; Helderberg limestone; Oriskany sandstone; quartz; gypsum; calcite; iron pyrites; dolomite; slickensides; and veins.

SUMMARY AND GENERALIZATION. The Devonian and Upper Silurian rocks outcrop along Cayuga Valley because of their southward dip, and because of their dissection by the denudation due to weathering, running water and ice. As we go northward we come to successively lower strata. Name them from

the Ithaca Group to the Salina. See page 85. Most of these rocks are shales. What does that indicate as to the conditions accompanying their deposit? There are many ripple marked layers. What does that show? Some of the rocks are limestones. What does that indicate? There are numerous sandy layers and one coarse sandstone. What do these facts tell about changes in conditions? Salt tells of still further change; What is it? South of the outcrop of the salt and gypsum the rocks are folded, faulted, and slickensided far in excess of anything further south in the Cayuga Valley. This localization of the disturbance points to local causes as the probable explanation.

NOTE. In report write a clear statement of the succession of strata in the Cayuga Valley, their variation in characteristics and the causes for these variations. Also describe the disturbances noted and state the explanations considered.

REFERENCES. Tarr's Geology pp. 287–290; Geikie, pp. 548–556.

EXCURSION XII.—TO SOUTH HILL.

OBJECT—A GENERAL VIEW OF THE ITHACA REGION FOR PURPOSE OF REVIEW.

Class will meet at 2:20, at the South Hill Bridge, which crosses Six Mile Creek near the south end of Stewart Avenue. Take *Ithaca*, *Genoa* and *Dryden* sheets.

(A) ON THE HILLSIDE, notice the numerous glacial striæ. Take their compass direction. How does the depth of soil compare with that at the E. C. & N. Station? Why this difference?

(B) IN THE QUARRY: Note the stratification, position of the beds, joint planes and fossils. Compare observations with those previously made on similar phenomena. What is being quarried? Account for the differences in texture.

(C) AT SPUR OF HILL: Note the terraces. What can account for these?

(D) AT THE SUMMIT: Note the extensive dissected plateau. Look for broad preglacial valleys; for interglacial (?), and postglacial gorges. Observe the lake deltas and the elevated delta terraces opposite the creek mouths. Trace the moraine on your maps. Account for the plateau; for the different kinds of valleys; for the delta terraces; for the moraines. Consider the effect of an

gradual melting back. What will happen in the way of erosion? Where will erosion be greatest? Where least? Where will most deposit be made? Where will temporary lakes be formed? What will be deposited in these lake waters on the margin? In the bottom?

NOTE. In your report state the general geological history of the Ithaca region :—the Devonian sea; the Carboniferous uplift; the long denudation; the advance of the ice; its work of deposit; the withdrawal of the ice; its moranic deposits; the ice-dammed lakes and their deposits; the probable interglacial period and interglacial gorges; the postglacial changes in stream courses; and the formation of the gorges and waterfalls.

EXCURSION XIII.

CLASS OBSERVATIONS.

Near the close of the year an excursion will be made for the purpose of testing the results obtained by the students. The Instructor will go as guide, and the students will make their own observations and interpretations, and be prepared at the close of the excursion to state these observations and defend the conclusions.

EXCURSION XIV.

MAKING OF A GEOLOGICAL MAP.

A small area will be surveyed by each section. The Instructor will construct a plane table map, and the students will assist him in obtaining elevations, measuring distances, and locating outcrops. Each student will copy this map and from it construct a geological map of the area undertaken. He will also be prepared to make sections across the map to show the structure. The object of the excursion is to give a first lesson in the methods employed in making geological maps.

EXCURSION XV.—VOLUNTARY EXCURSION TO WILKES BARRE AND HAZLETON.

A TRIP TO THE ANTHRACITE COAL MINES.

Leave Thursday noon, return Saturday evening. Expense

(A) ON THE TRAIN. (*a*) Train passes through the terminal moraine in the valley south of Ithaca. (*b*) Strata, nearly horizontal wherever outcrops are seen. They belong to the *Chemung* division of the Devonian, and the layers farther south form the uppermost beds of the Devonian. The rocks are shale and sand layers, becoming generally coarser toward Wilkes Barre. Notice cross bedding. (*c*) Notice effect of Susquehanna in meandering, and thereby broadening valley bottom. What relation to meanders do the steeper hill slopes bear? What observations do you make regarding weathering? (*d*) As the mountains are approached, the signs of disturbance begin, increasing toward Wilkes Barre. Just before entering the broad Wyoming valley the rocks are upturned to form the western arm of a long syncline. Note direction of dip. First comes the Pocono sandstone; then the Mauch Chunk red shale; then the Pottsville conglomerate; and finally the Coal Measures, which occupy the middle of the valley. Why are the mountain ranges made of Pocono sandstone and Pottsville conglomerate? Why is there a valley between these two layers?

(B) THE SYNCLINE extends from southwest to northeast to a point beyond Scranton in the north, and beyond Wilkes Barre in the southwest. Why should the coal there be anthracite rather than bituminous, as is the case farther west? Why is it preserved at this particular point? Do you suppose there was ever coal to the east and west of the valley where the mountain ranges now stand? While the valley is a broad syncline, there are numerous minor folds revealed in mining. Note the slickensides in the mines. What causes them? Examination of coal mine; of coal breaker; of culm piles.

(C) LEAVING WILKES BARRE FOR HAZLETON. Train climbs the eastern side of the syncline. Note direction and amount of dip. Going up the mountain side are you ascending or descending geologically? Note and explain the valley between the Pocono sandstone and Pottsville conglomerate. The hilltops are very barren. Give the reasons. This is characteristic of coal regions. Suggest a reason for the opposite condition in the Susquehanna valley near Wilkes Barre. Note the influence of coal on settlement, especially near Hazleton. Note great abundance of conglomerate near Hazleton. Why is this so?

(D) HAZLETON REGION. This is also part of a syncline, but much less of the coal is left than at Wilkes Barre. In fact there are many minor basins representing the bottoms of minor synclines—a part of a large one—(This condition resembles the minor synclines in the mines of the Wilkes Barre region). Influence of this condition on mining methods. Visit the coal strippings, breakers, and culm piles. Notice plant remains in the shales. What are they?

SUMMARY AND GENERALIZATION. In the course of the folding of the Appalachians some of the coal was folded in deep synclines and changed to anthracite. Its depressed condition has protected it in a few spots, while in general it has disappeared from the mountains because of their elevation and long denudation. These coal basins offer many illustrations of geological principles. State them. In writing your report give attention to the geological aspects of the excursion and not to the engineering side. In addition to topics brought forward in the above outline, state what evidences you have seen that point toward origin of coal; what evidence you have seen of former mountain building forces; also evidences of the existence at present of remnants of this mountain building force. What conditions favor bending of the layers in place of breaking? Is there any sign of breaking? What kind of fossils do you find? What is their meaning? What would you say regarding man's importance as a geological agent? In the report also include a cross section of the Wilkes Barre region and also one of the Hazleton region, made from the geological model of the anthracite region of Pennsylvania.

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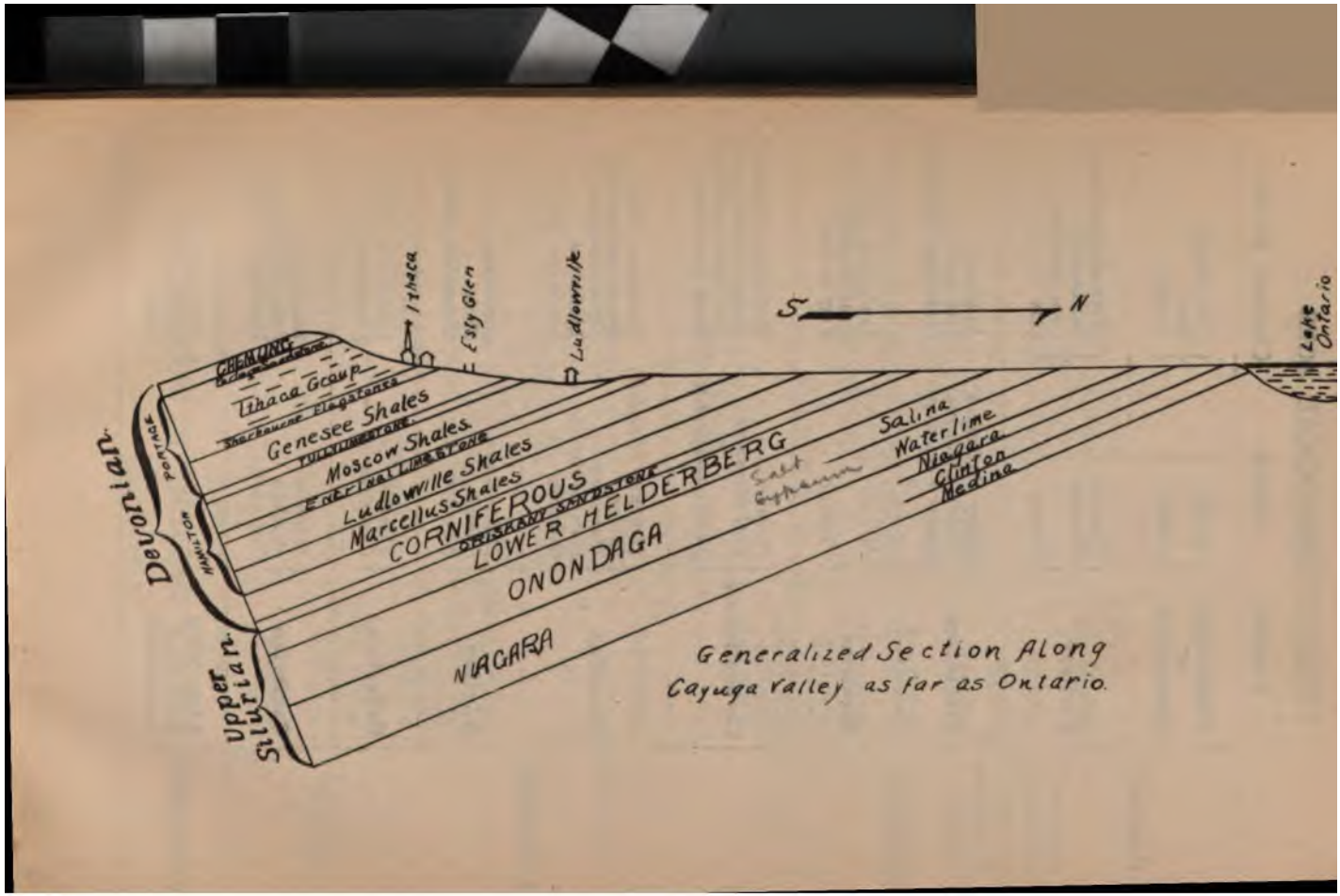
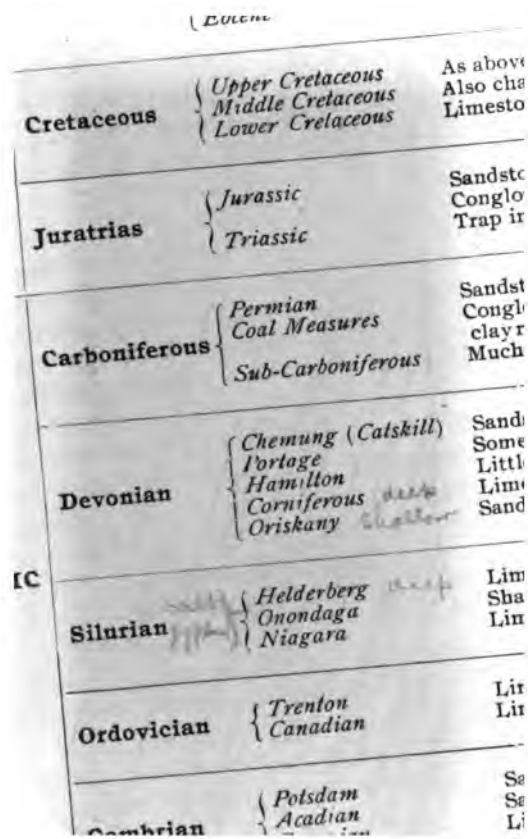


Generalized Section Along
Cayuga Valley as far as Ontario.



Cretaceous	*Upper Cretaceous* *Middle Cretaceous* *Lower Cretaceous*	As above Also cha Limesto
Juratrias	*Jurassic* *Triassic*	Sandsto Conglo Trap in
Carboniferous	*Permian* *Coal Measures* *Sub-Carboniferous*	Sandst Congl clay r Much
Devonian	*Chemung (Catskill)* *Portage* *Hamilton* *Corniferous* *Oriskany*	Sand Some Littl Lime Sand
Silurian	*Helderberg* *Onondaga* *Niagara*	Lim Sha Lim
Ordovician	*Trenton* *Canadian*	Lim Lim
Cambrian	*Potsdam* *Acadian*	Sa Sa Li

ARCHEAN	Algonkian Huronian Laurentian		Plutonic rocks. Gneiss. Schist.

THE STRATA INCLUDED IN EXCURSIONS.

	GROUP.	STAGE.	REMARKS.
CARBONIFEROUS	Coal Measures		Beds of clay ("slate") and sandstone, for the most part, with coal seams. At Wilkes Barre Coal Measures are 857 feet thick with 85 feet of coal.
	Pottsville Conglomerate		Gray and white conglomerate with beds of sandstone. Some coal. 1750 ft.
	Mauch Chunk		Soft red shales and clayey sandstones in some places 3000 feet thick, usually much less.
	Pocono or sub-Carboniferous		Sandstones with beds of conglomerate some thin seams of coal. 2500 feet.
	Chemung		Sandy shales and thin bedded sandstones 1500 feet.
DEVONIAN	Portage	*Portage (Ithaca group)*	Shales, sandy shales, and flagstones. Concretions in many layers. 1000 ft.
		Genesee Shale	100 to 1500 feet thick, color black, fossils few.
	Hamilton	*Tully*	Limestone, 10-20 feet thick.
		(1) *Moscow Shale.* (2) *Encrinal Limestone* (3) *Ludlowville Shale*	Sandy in east. Fine grained in west. Makes excellent soil. 1000 feet thick.
		Marcellus Shale	Dark, often black (why?). 100 to 200 feet thick.
	Upper Helderberg or Corniferous Limestone		Contains much chert. 30 to 50 feet thick.
	Oriskany Sandstone		20 feet thick.
	Lower		

LABORATORY WORK.

MINERALS.

GENERAL DIRECTIONS. While it is necessary to scratch some of the minerals, each student is requested to handle all specimens with care. The better specimens ought not to be scratched at all; and in each case a very tiny scratch, on an inconspicuous part of the specimen, will serve as well as a long cut. The laboratory fee has been reckoned on the minimum average required to replace damages to specimens and to keep the collections in good condition. Therefore, any apparently unnecessary mutilation or loss of specimens can be met only by a general increase in the laboratory fee.

The class is also requested to use care in replacing the specimens in their proper trays, which are numbered for that purpose. Misplaced specimens will cause confusion for those studying them. In studying specimens be sure that each is in the proper tray before examining it; this can be determined by comparing the number on the specimen with that in the tray.

There are six sets of each object, so that Drawers 1 to 6, for example, have specimens illustrating exactly the same phenomena. The Drawers are numbered with the Arabic numerals and the specimens with Roman numerals; thus the specimen in the third tray, of the sixth drawer will bear the number 6–III.

Rocks being made up of minerals, and each rock species being known by its mineral composition, it is necessary to first become familiar with the minerals. Minerals are determined by their different properties, such as hardness, cleavage, lustre, etc.; these properties are illustrated in Drawers 1–18. Although the mineral grains in the rocks are often very small, their characteristics are usually easily distinguishable. In all cases the student in petrography can determine them with a microscope.

The books referred to in the notes will be found on the reference shelves in the laboratory, and the students are required to look these up and have a general knowledge of the contents of the pages referred to.

Careful laboratory notes are to be kept in this book which is to be handed in at the end of each term. All the questions should be answered and a record kept of your observations and conclusions. The laboratory notes are not to be written up separately for handing in ; but the notes, as taken in the laboratory periods, will be called for at the close of the term.

PROPERTIES OF MINERALS.

(Tarr's Elementary Geography, p. 33.)

DRAWERS 1–6: HARDNESS, COLOR AND EARTHY APPEARANCE.

(Dana's Minerals and How to Study Them, pp. 74–78; Supplementary references: Dana's Text Book of Mineralogy; Brigham's Text Book of Geology, pp. 192–193; Idding's Rosenbusch Physiography of the Rock-making Minerals; Scott's Introduction to Geology, p. 13.)

Hardness: Each mineral species shows a constant degree of hardness. Talc is the softest and diamond the hardest; eight others have been selected to illustrate the intermediate grades of hardness, and these ten minerals form a scale which can be used to determine the hardness of others. Specimens I–IX illustrate this scale. Diamond, number 10 in the scale of hardness, is not included. Test these carefully to see how they vary in hardness. For instance, will IV scratch VIII? Where in the scale of hardness will XI, XVI and XIX fall?

Color (Dana's Minerals, 90–92): There is a great range of color even in minerals of the same species. In some minerals the color is due to the inclusion of foreign matter; witness IV and XII. Specimens X–XIX illustrate some of the colors of minerals, and there are many others. While many of the minerals, as quartz and feldspar, vary in color, others, like azurite, malachite, and cinnabar, always have the same color, varying only in intensity. Can you suggest a reason for this difference in color of minerals, say between quartz, which is variable, and azurite, which is uniform?

Earthy Appearance: While some minerals are bright and shiny, as in some of the previous specimens, others, like XX–XXIII, are dull and earthy. Suggest a reason for this.

[redacted]

DRAWERS 7–12: CLEAVAGE, FRACTURE, SPECIFIC GRAVITY, AND MAGNETISM.

Cleavage (Brigham's Geology 193; Dana's Minerals, 70–73, 354): Trays I–VII. Many minerals split easily in certain directions along planes that are smooth and bright. This is known as cleavage. Some minerals cleave in only one direction, others in two or more directions. In how many directions does mica cleave? Calcite? The other minerals? Find illustrations of cleavage in Drawers 1–6, giving the names of six minerals that show it. In each case state the number of cleavage directions. In a study of mineralogy cleavage is one of the most important mineral characteristics.

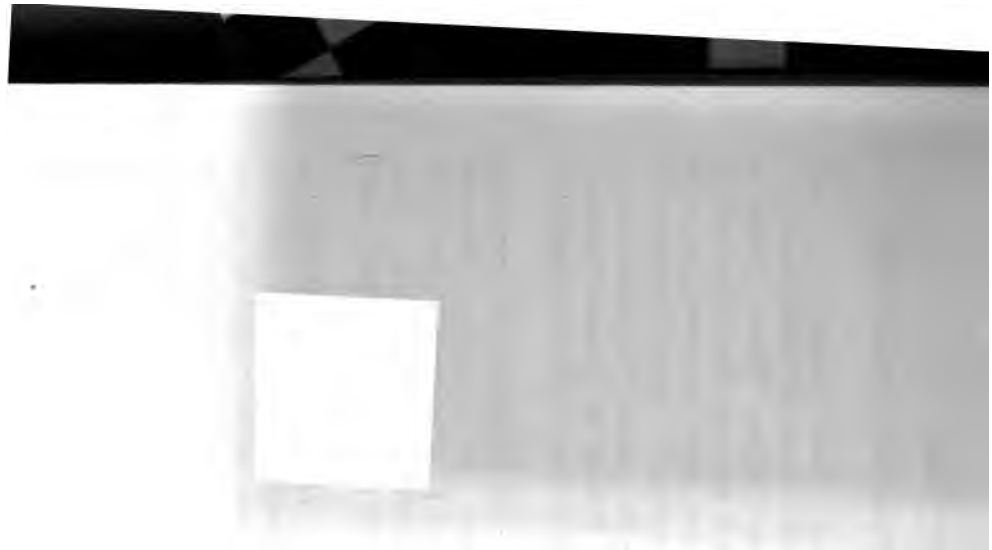
Fracture (Dana's Minerals, 73–74): An irregular break, not along cleavage planes, is called fracture. Do not confuse this with cleavage. Notice this in specimen IV. Specimens VIII to XI illustrate types of fracture. Notice it in quartz (XV). This mineral has no cleavage and there are others that have none. Find some of these.

Specific Gravity: You have, of course, noticed that the weight of the minerals varies. Specimens XII–XIX are selected to illustrate this variation in a general way. Considering the scale to comprise eight minerals, locate in it IV and three of the minerals in Drawers 1–6. Without special apparatus the exact specific gravity cannot be determined, but by a simple apparatus one can accurately determine the specific gravity of a mineral.

Magnetism (Dana's Minerals, 96): Notice the magnetism of XX. Try the magnet on XXI, XXII and XXIII. Try the nails on them.

DRAWERS 13–18: LUSTRE, AMORPHOUS, DOUBLE REFRACTION, AND CRYSTAL FORM.

Lustre (Dana's Minerals, 88–90; Brigham's Geology, 193): The appearance of reflected light varies in different minerals, entirely apart from their color. This appearance is called lustre. The kinds of lustre most commonly distinguished are glassy or vitreous, pearly, resinous, metallic, silky, waxy, and dull or earthy. Some of the more pronounced lustres are illustrated in specimens I–VI. In Drawers 1–12 find minerals with some of these lustres. Why are some minerals without lustre?



Amorphous (Dana's Minerals, 63): Notice the absence of lustre in trays VII–X; also trays XX–XXIII in Drawers 1–6. Also notice that specimens VII–X of Drawers 13–18 have no very definite form. This is quite in contrast to the definite form in the crystal and cleavage pieces.

Crystal Form (Scott's Geology, 9–10): (Do not scratch these, XII–XXI.) Under favorable conditions many minerals develop a geometric form called a crystal. There is a great range among these forms, and the crystals may vary considerably even in the same mineral species. But they are built up under certain definite laws so that crystal forms have been classified into systems. Although the crystal faces may vary in size on different individuals of the same species, the angles between two corresponding faces are always constant. The study of these, however, belongs to mineralogy and crystallography. The specimens in these drawers are merely to illustrate some of the commoner forms. What is the difference between crystal and crystalline? How would you distinguish between a crystal face and a cleavage plane?

Double Refraction: Notice the effect of Specimen XI upon light, as shown by the appearance of the label beneath. This property of marked double refraction is one of the less common properties of minerals. All minerals have some refraction, but few equal Iceland Spar (a form of calcite). The degree of double refraction varies in different minerals which possess this property. It also varies in different directions in the same mineral. This feature can be properly studied only with a microscope.

ROCK-FORMING MINERALS.

(In taking notes it is not intended that separate notes should be made on each specimen, but general notes to show the characteristics of each species and whether these characteristics are constant or variable. Some of the facts called for below will have to be looked up in the text book.)

DRAWERS 19-24. QUARTZ, FELDSPAR, CALCITE, AND DOLOMITE.

Quartz (Brigham's Geology, 194; Scott's Geology, 15–16; Dana's Minerals 273–284; Tarr's Geology, 37–40), I–IX: Several varieties. Note color, lustre, hardness, fracture, approximate specific

	Cleavage.	Lustre.	Fracture.	Common Colors.	Composition.	Hardness.	Specific Gravity.
Quartz	none	vitreous	conchoidal	white, pink, etc.	SiO_2	7.	2 65
Orthoclase	Right angles, 2 directions	vitreous	uneven to splintery	white, green or flesh color	SiO_8Al (KNa)	6.	2 6
Plagioclase	Same, striated on one cleavage pl.	vitreous	uneven	white, brown or greenish	SiO_8Al (NaCa)	6.	2.7
Calcite	Three perfect	pearly	difficult, conchoidal	white to transparent	$CaOC_3$	3.	2.7
Dolomite	perfect	vitreous	irregular	white or gray	$CaMg(CO_3)_2$	4.	2.9
Gypsum	three directions	pearly	fibrous	white, gray or trans.	$CaSO_4+H_2O$	1.5–2	2.3
Mica	laminar, one good	vitreous to pearly	uneven	black, brown or colorless	$Sio_4Al_2Fe_2Mg_2$	2 3	3.
Hornblende	prismatic, good	pearly or silky	uneven	black, brown or green	Silicates of Fe Al Ca Mg	5.6	3.2
Pyroxene	prismatic, distinct	vitreous	uneven	green to black	$SiO_3Al_2O_3\{^{Mg}_{Fe}$	5 5	3.4
Olivine	distinct 2 direct.	vitreous	conchoidal	green or brown	$SiO_4(MgFe)_2$	7.	3.4
Garnet	none	vitreous	splintery	red or brown	$(SiO_4)_3(CaFe)_3Al_2$	7.	3–4
Pyrite	none	metallic	uneven	yellow	FeS_2	6.5	4.9
Siderite	perfect	vitreous	uneven	brown, gray or yellow	$FeCO_3$	4.	3.8
Limonite	often fibrous	metallic or earthy	irregular	black, brown or yellow	$Fe_2O_3+H_2O$	5.5	3.6–4
Magnetite	none	metallic	uneven	black	FeO, Fe_2O_3	5 5–6	5.1
Hematite	none	metallic to dull	irregular	red to gray	Fe_2O_3	5.5	4 5–5

gravity (whether heavy or light), and crystal faces, when the specimen has crystal form. Can you explain any of the differences observed? Which of the specimens are amorphous? Find out the chemical composition.

Feldspar (Tarr's Geology, 40–42; Brigham's Geology, 194; Scott's Geology, 16–17; Dana's Minerals 284–292), X–XIV: Note color, lustre, hardness, cleavage, etc. Why are some glassy and others dull? What is the difference between orthoclase and plagioclase (Compare specimens XIII and XIV)? Find out about the chemical composition of feldspar. What are two common minerals in XI? How do feldspar and quartz compare in hardness? cleavage? lustre? Learn to tell them apart.

Calcite, XV–XXII (Tarr's Geology, 42–43; Scott's Geology, 22–23; Dana's Minerals, 247–252): Notice color, hardness, lustre, cleavage, crystal form. Do not scratch the crystals. Try the effect of weak hydrochloric acid on calcite; on quartz; on feldspar. Compare and contrast calcite with feldspar; with quartz. How can they be told apart? Will the table (p 101) aid you in this? What is the chemical composition of calcite?

Dolomite, XXIII–XXIV (Tarr's Geology, 43–44; Brigham's Geology, 196; Scott's Geology, 23; Dana's Minerals, 260–262): Examine this in a similar way. What effect has the acid on it? Try warm acid. How does the composition of dolomite differ from that of calcite?

The first three of these are very important rock forming minerals. Which should you expect to be the most durable? Why? Which least? Why? Read something in each of the textbooks about the effect of weathering on these minerals. In what rocks are they common?

DRAWERS 25–30. GYPSUM, MICA, HORNBLENDE, PYROXENE, OLIVINE, IRON ORES.

Gypsum (Selenite) I–V (Tarr's Geology, 49–50; Scott's Geology, 5; Brigham's Geology, 197; Dana's Minerals, 256–258): Study in same way as other minerals. Compare and contrast with feldspar, calcite, and dolomite. What is its composition?

Mica (Biotite, muscovite), VI–IX (Tarr's Geology, 45; Scott's Geology, 18–19; Dana's Minerals, 303–310; Brigham's Geology, 195):

Study mica in the same way. Compare and contrast it with gypsum. Notice that there are a large number of individuals in the biotite specimen (VIII). With this in mind, compare VII and VIII. Find the difference between muscovite and biotite.

Amphibole (Hornblende), X–XIV (Tarr's Geology, 46-47; Brigham's Geology, 195; Dana's Minerals, 296–298): Study as before, comparing and contrasting with mica. How do they differ? As in VIII among the micas, so here in XII and XIII (hornblende) there are many individuals. Compare with X. What other minerals do you find in XI and XIV? In comparing hornblende and mica, notice especially the lustre and cleavage.

Pyroxene (Tarr's Geology, 46–47; Dana's Minerals, 292–296): Read to find the difference between hornblende and augite.

Olivine (Dana's Minerals, 212; Scott's Geology, 20–21): State its other characteristics. This is a green glassy mineral. In what kind of rocks is it found? To what does it weather?

The Iron Ores: XVII–XXII, Magnetite, Hesmatite, Limonite, Siderite (Tarr's Geology, 47-49; Brigham's Geology, 197–198; Scott's Geology, 24–26; Dana's Minerals, 217–224): Study each. Notice their streak on the streak plates. What about their lustre? Their specific gravity? Compare and contrast with pyroxene and hornblende. Notice the large number of individuals in XVIII and XXI. Try the magnet on each. Find out the chemical composition of each. Learn from the textbook the importance of each of these minerals, in what rocks they occur, their characteristics, etc.

Each student will now be given a number of unnamed mineral specimens to determine, handing in the results of his determinations as a sort of examination test.

DRAWERS 31–34: MISCELLANEOUS MINERALS.

The minerals previously studied are by far the most abundant of all. Besides these there are many hundreds of less common minerals, a few of the most abundant of which are arranged in these trays for supplementary study.

While the class will not be held responsible for a knowledge of these, as they will of those previously studied, they are never-

TABLE TO ILLUSTRATE THE CLASSIFICATION OF THE IGNEOUS ROCKS.

It is important that each student should be so familiar with this table that he can reproduce it readily.		**ACID ROCKS.** Generally light-colored.		Intermediate.	**BASIC ROCKS.** Generally dark-colored.	
		Feldspar; also, mica, hornblende, or, rarely, augite.		**Feldspar chiefly plagioclase.**		**Feldspar-free rocks.**
		With quartz.	*Without quartz.*	*Horn-*	*Pyroxene or pre-dominant.*	
VOLCANIC or effusive.	**Glassy or fine-grained; usually porphyritic. Intruded at or near the surface. Lava flows and volcanic ash.**	Rhyolite. Quartz-Porphyry.	Trachyte. Porphyry.		Basalt. Diabase.	Rare.
PLUTONIC or tinrusive.	**Coarse-grained, rarely porphyritic. Intruded at great depths.**	Granite.	Syenite.	Diorite.	Gabbro.	Peridotite often changed to Serpentine.

theless expected to examine these minerals, noting their color, lustre, specific gravity, hardness, etc. Examine especially the specimens of iron pyrite. What is its crystal form? Its lustre? Its composition?

IGNEOUS ROCKS.

STRUCTURE AND TEXTURE.

DRAWERS 35–40. (Kemp's Handbook of Rocks, 12 and 56–57; Scott's Geology, 189–196. Before studying these, read up pages 54–70 in Tarr's Geology.)

What causes the ropy surface on lava (IX)? What are dikes, laccoliths, bosses, cones, sheets, tuff? What is an amygdule? An amygdaloid? How do amygdaloid (I) and cellular basalt (VI) differ?

What is porphyritic structure? What are porphyritic crystals or phenocrysts? How formed? Notice how phenocrysts vary in size, and compare trays III and IV for extremes. The latter rock, on first sight, appears almost even-grained. How do phenocrysts differ from amygdules in origin and structure? What minerals can you find filling amygdaloidal cavities? forming porphyritic crystals? What does this difference signify?

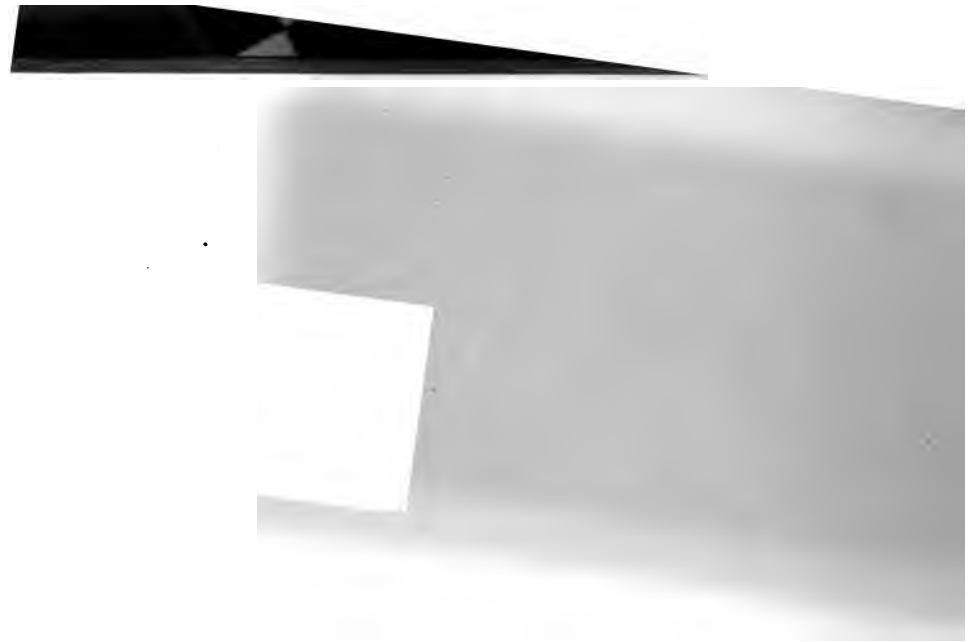
What is meant by cryptocrystalline and holocrystalline? Explain the cavities in VI and VII; the roughness of VII; the lightness of VIII (pumice) (Compare with II); the banding of X (obsidian); and the lines in III (petrosilex).

How do you explain the variations in coarseness of texture? Note the differences in color? What would explain that? What prominent minerals can you detect in some of these specimens? For classification of igneous rocks see table on p. 110; also pages preceding p. 66 in Tarr's Geology.

Find out what volcanic tuff is. What is the difference between volcanic ash and volcanic tuff? What are volcanic bombs?

VOLCANIC ROCKS.

DRAWER 40 A: DIKES. What are dikes? Why are these so fine-grained? Do different dikes vary in grain? Can you find any variation in grain in the same dike? How do dikes effect the structure and composition of contiguous rocks? What effect



will they have on limestone, chalk, clay, sandstone, and coal? Are there dikes near Ithaca? Examine large specimens in laboratory.

DRAWERS 41–46, ACID; 47–52, BASIC; 53, MISCELLANEOUS (Tarr's Geology, 56–66; Kemp's Handbook, 20–30 and 34–46): The first six contain the more acid rocks, the second set of six the more basic ones. In studying the volcanic rocks determine first their structure; whether holocrystalline or cryptocrystalline, porphyritic or amygdaloidal, compact, pumiceous, or scoriaceous; and secondly their mineralogical composition. Do any of the specimens show evidences of flow structure? Which are they? In trays I and II, Drawers 41–46, are specimens of spherulites; what special characteristics do they show?

From the specimens in the different trays determine the general characteristics of the rhyolites, trachytes, andesites, porphyrites, quartz porphyries and basalts. What causes the bands in obsidian (IV and V)? What is the difference between obsidian and pitchstone, both in appearance and in chemical composition? What evidence is there that rhyolite is a volcanic rock? What difference can you see between a quartz porphyry and a rhyolite? between rhyolite and trachyte? between dacite and rhyolite? between dacite and andesite? also between trachyte and andesite? Locate each of the specimens in the table of igneous rocks (p. 110.) Why should some be coarser in grain than others? How do you account for the origin of the porphyritic structure which is so prevalent in these rocks? (It is best to read up some of these points). In Drawers 47–53, see if you can find any distinction between basalt and andesite. See if you can also determine the green glassy mineral (XIII) by reference to the specimens of rock-forming minerals.

PLUTONIC ROCKS.

DRAWERS 54–59: (Tarr's Geology, 55, 62; Hemp's Handbook, 30–57; Supplementary—Gilbert's Geology of the Henry Mountains; Russell's Volcanoes of North America; Dana's Characteristics of Volcanoes).

These are the rocks that have cooled below the surface. How does this fact influence their structure? What is the structure and mineralogical composition of each of the following: granite, syenite, diorite and gabbro? Tabulate these facts in order to

aid you in making the comparisons called for below. Why are the rocks which belong to the granite end of the table usually light in color, while those of the gabbro end are often dark? What difference do you find between granite and syenite? syenite and diorite? diorite and diabase? syenite and peridotite? Note also the difference between granite and rhyolite? syenite and trachyte; diorite and dacite; gabbro and diabase. What is gabbro diorite? Why are the plutonic rocks prevailingly coarse-grained? Would you expect to find coarse-grained rocks in lava flows? Why? If these rocks are plutonic how does it happen that we find them in quarries at the surface? Notice the porphyritic granites, but remember that they are exceptions. What is pegmatite?

CLASTIC OR FRAGMENTAL ROCKS.

(Tarr's Geology, 71–75; Kemp's Handbook, 58–61 and 82–83; Scott's Geology, 204–205; Brigham's Geology, 201–215.)

These exhibit certain general properties, such as stratification, color, texture, and mineral composition. The first three of these are determinable with the naked eye; the latter is not visible unless the rock is coarse-grained.

DRAWERS 60–65: STRATIFICATION AND COLOR.

Stratification: How can you explain variation in color in banded sandstone (I)? Do you notice any stratification in II? What are the evidences of it? Parallel to which faces does it extend? Describe and explain III. In what direction does the stratification extend in micaceous sandstone (IV)? Why? Explain the shining faces on the surfaces. What causes the thin bedding in shale (VI)? and slate (VII)? What does the absence of lamination in shaly sandstone (VIII) and marble (IX) indicate? Summarize what you have learned of stratification. Have you seen any of these facts in the field? If so, where?

Color: The entire drawer may be considered an illustration of variation in color among rocks, though the series especially selected for this extends from IX to XXI. What would cause a black color? A red? A yellow? A blue? A pure white? Trays IX, XI, XIV contain specimens made of carbonate of lime. Test these with the acid. XI is sugary white; XIV is sugary but

colored; while IX is very dark and massive. What would cause these differences? What mineral do you find in sandstones, (XII, XIII and XVI)?

DRAWERS 66–71. TEXTURE AND CONSOLIDATION.

In trays I–V are illustrated variations in texture and clastic rocks. Study these and explain what has happened. What minerals can you find in conglomerate and sandstone, (I–IV)? Why is there so much quartz? What has become of the other minerals? Do you find quartz in shale (V)? Of what is this probably made? VI–VII, VIII–IX and X–XI are a series to illustrate the formation of limestone, sandstone and conglomerate. Why are there so many shells and so little clay and sand in VI and VII? By what is VII cemented? Where does the cement come from? How? IX and XI together with I and II illustrate consolidation of sandstone and conglomerate. Sandstone may be cemented by three different substances. What are they? By what are I and II consolidated? What is the difference between a sandstone and a conglomerate? Where would we draw the line? Do you know what quartzite is? XIII and XIV represent consolidation of clay rocks. Add to this series tray V of same drawer. XIII is from a clay bank. Why is it so compact? Summarize what you have learned about the cementing materials of clastic rocks.

DRAWERS 72–77. CONGLOMERATES: (Tarr's Geology, 75–78; Brigham's Geology, 203; Scott's Geology, 207.)

Study these carefully and make a summary statement of what you observe, regarding differences in texture, in consolidation, in form of fragments, and in material composing the pebbles of the conglomerates? In what specimens is there some other material? What is the most common mineral in the pebbles of the specimens, if you look carefully, you will find fragments of feldspar. In which ones do you find them? These are mixed with quartz. Bearing in mind the reasons for the abundance of quartz in the conglomerates, what does this presence of feldspar show? A rock of this kind is often called an arkose. XVI is an especially fine example.

DRAWERS 78–83, SANDSTONES (Kemp's Handbook, 63–69; Scott's Geology, 206; Brigham's Geology, 202; Tarr's Geology, 78–80).

Study these carefully and write a summary, as in the case of the conglomerates.

Which should you call IV and V, conglomerates or sandstones? What would a sandy conglomerate be called? A pebbly sandstone? Of what mineral are sandstones usually made? Why? Might sandstones be made of some other mineral? What? Some sandstones contain little cavities lined with limonite. This has been formed by the decomposition of pyrite grains. Find some examples of this. Why are there few fossils in sandstones? Explain the color of the different specimens. What cements can you determine? Explain the lamination of XIII. Explain the absence of banding in most of the others. What is a freestone (consult book)? What does the presence of feldspar indicate?

DRAWERS 84–89, CLAY ROCKS (Scott's Geology, 207–208; Brigham's Geology, 204; Tarr's, Geology, 80–81; Kemp's Handbook, 67).

Study these carefully. What are the characteristics and how can you explain them? Why is there so much black or dark colored shale? Fossils are more abundant in shales than in sandstones. Why? What is the difference between sandstone and shale? Where should the line be drawn? Are our flagstones shales or sandstones? What is the meaning of the term argillaceous sandstone? Arenaceous shale? Would you expect a gradation from shale to limestone? Why? Where would that line be drawn? What is argillaceous limestone? Do the different species of clastic rocks grade into one another?

ORGANIC ROCKS.

DRAWER 90, BERMUDA ROCKS: Of what is the sand made in I and II? Examine the other specimens. Of what are they made? How cemented? Bermuda above the sea is entirely made of this material, generally windblown. The process is still in operation and cementing is still going on.

DRAWERS 91-96, LIMESTONES, (Scott's Geology, 211–214; Brigham's Geology, 205; Kemp's Handbook, 71–73; Tarr's Geology, 83–85 and 89–90). Many limestones are organic but some are chemical precipitates. How could you distinguish them? What is coquina?

Compare it with the Bermuda rocks, Drawer 90. What relation does it bear to limestone? Compare I and II, III and IV, with other specimens in the drawer. What differences in the limestone do you find? Explain them. Of what mineral is limestone composed? Compare the limestones with the clay rocks, Drawers, 84–89. What resemblances do you find? What differences? How can you tell them apart? In what different ways may limestones be formed?

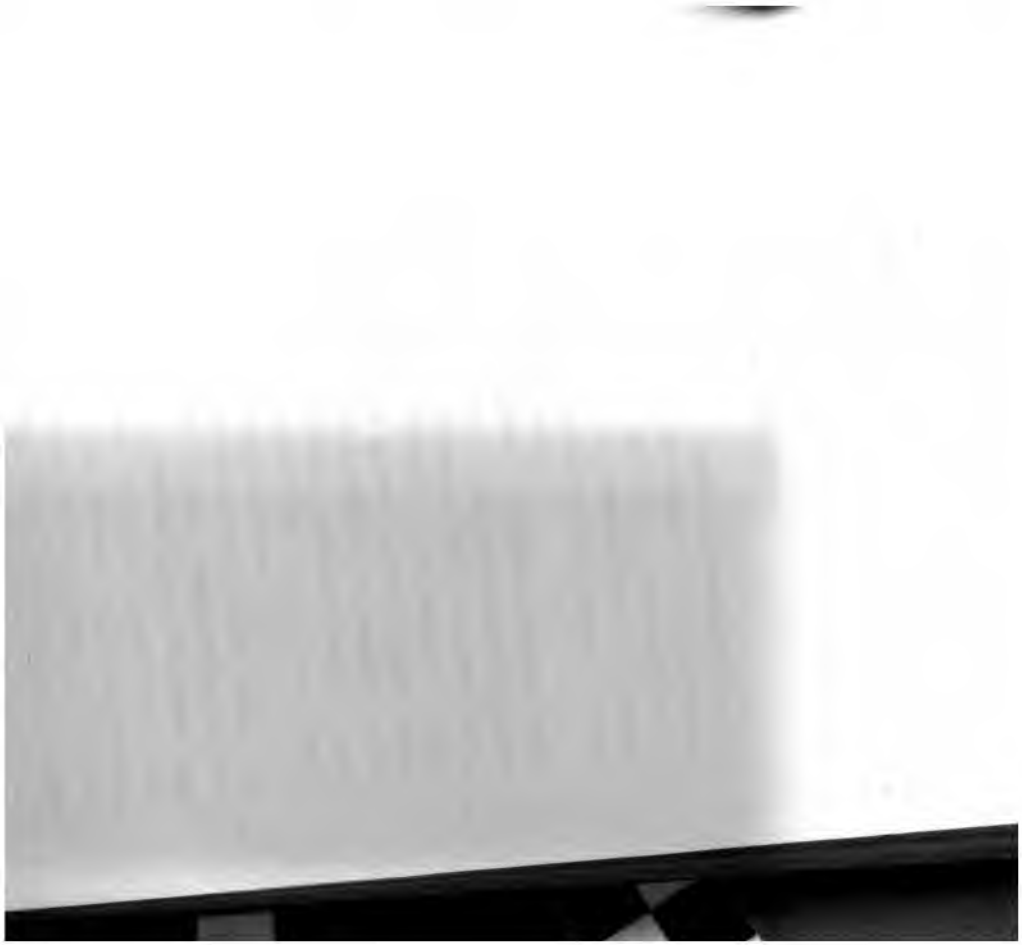
DRAWERS 97–102, COALS (Scott's Geology, 215–216; Tarr's Geology 92–94, Brigham's Geology, 196–197; Kemp's Handbook, 76–77): How is coal formed? Series I–V should suggest an answer. What differences are noticeable between them? What are the causes of these differences? What happens in the process? What is the difference between bituminous and anthracite coal? Between lignite and bituminous coal? Find the chemical composition of these. Where are coals found? In what geological ages was coal found? Is coal forming now?

DRAWERS 103–106, MISCELLANEOUS ORGANIC ROCKS: Limestone Series, I–VII. Note mode of consolidation of coquina (I). What is chalk? (VIII, IX)? Marl (X)? Infusorial earth (IX)? What is the origin of the phosphatic rocks? Examine specimens XII, XIII, XV–XVIII. What is Gilsonite (XVI)?

CHEMICAL ROCKS.

MISCELLANEOUS CHEMICAL ROCKS, DRAWERS 107–110: In what way is salt accumulated (I, II)? Gypsum (III, IV)? Gypsum and salt are sometimes found in the same deposit, but in separate layers. Why should one be deposited before the other? What are oolites and pisolites? Calcareous tufa? Flint nodules? Chert? State as many conditions as you can under which chemical deposits of mineral are made. Do you suppose native copper (XIX) could be deposited?

DRAWERS 111–113, YELLOWSTONE ROCKS: Handle these very carefully, especially the choice specimens in Drawer 113. What differences do you find between silicious sinter and calcareous tufa? Which are deposited around geysers? What do such deposits tell us about the work that underground water is doing?



DRAWER 114 contains additional examples of chemical deposits. Determine, if possible, how they were formed. While they are all chemical deposits they were not all formed by simple precipitation.

METAMORPHIC ROCKS.

(Kemp's Handbook, 84–120; Scott's Geology, 287–288; Tarr's Geology, 98–99; and 366–378; Brigham's Geology, 209–214; LeConte's Elements, 193–194).

GNEISSES AND SCHISTS.

DRAWERS 115–120: Numbers 1–8 are called gneiss. What minerals can you find in them? Which of these are most abundant? How do they differ from the plutonic rocks? Account for the banded structure. From what may these rocks be derived? Under what conditions could a granite become a gneiss? How would you distinguish between such a gneiss and a granite? Give all the points of difference you can think of. What causes the banding?

Numbers 9–17 are called schist. Does schist split readily? Schists are named according to some prominent minerals which they contain, as mica schist, hornblende schist, quartz schist, etc. How many varieties can you find? Name them and give the number of each. Compare gneiss and schist. What is the origin of each? Might gneiss and schist come from the same rock? What causes the banding?

SLATE, SERPENTINE, QUARTZITE, GRAPHITE, AND MARBLE.

DRAWERS 121–126: Slate is formed by the metamorphism of clay rocks. During the process of metamorphism new planes of splitting, called cleavage, were produced. Can you see any trace of the bedding planes? What are the dark bands in the large specimens given you? How do slates differ from mica schists?

What is serpentine? How is it formed?

How does quartzite differ from sandstone? How is it formed?

Learn to recognize graphite. Learn how it is formed.

Marble is a term applied to limestones which have been made crystalline by metamorphic action. What differences are noticeable in the specimens? Account for the black specks in some. A black limestone is metamorphosed to a marble; what color will it have? What will become of the impurities?

GEOLOGICAL PHENOMENA.

DRAWER 127, PRESSED PEBBLES, ETC.: Specimen II is a metamorphosed conglomerate; I is a gneiss from the same region, produced from a conglomerate. What has happened in I? Compare it with a conglomerate to see the difference. Specimens III–VIII have also been metamorphosed somewhat. What has happened? What has happened in VIII and IX? Specimen IV is a conglomerate from the Coal Measures of Rhode Island and was formed when the coal was being deposited. IX is from the Green Mountains. Find out what events have occurred there which might account for this stretching. Study specimen X. Is this an artificial stone? The specimen furnishes good proof on this point. Study specimens XI–XIII. How can you account for the dents in the pebbles?

DRAWER 128, FOLDING (Look up these subjects in Tarr's, Geikie's or Brigham's Geology): Why did these layers bend rather than break? What explanation, other than folding, can you suggest for IX and X? What types of fold do we recognize? Which ones do you find in the trays?

DRAWER 129, JOINTING: What are joints? How are they formed? What facts can you observe in the study of these? What causes the columnar joints illustrated in the large laboratory specimens? What is the difference in the form of the joint blocks of slate and basalt?

DRAWERS 130 AND 131, FAULT BRECCIA AND SLICKENSIDES (Scott's Geology, 243–244; Kemp's Handbook, 59): Study these to see what they are. What causes them? How do slickensides differ from glacial scratches? Fault breccias from talus breccias?

DRAWERS 132 AND 133, CONCRETIONS: (Scott's Geology, 227-230; Brigham's Geology, 222–223; Tarr's Geology, 275–277). Of what are they made? How do they vary? What is their origin? What makes some spherical? Why are some flattened? What gives some an elongated form? How is 132–XIII formed?

WEATHERING.

Weathering is the change which takes place in rocks due to atmospheric and organic agencies. How does it differ from metamorphism? (See weathering in Tarr's Geology, Brigham's Geology and Scott's Geology. Supplementary—Kemp's Handbook, Merrill's Rocks and Rock Weathering, also Geikie's Text-Book, 345–356 and 671.)

DRAWER 134, PLANT INFLUENCE, ETC.: Specimens II–VII. How do these lichens, etc., cling to the rock? How may this aid weathering? Account for the yellow color in VIII and XII. For the cavities in XIII. What does XI illustrate?

DRAWER 135, WEATHERING OF FOSSILIFEROUS ROCKS: Why do some (as VII) have their fossils projecting, while others (as XXII) have cavities? Account for the yellow and red colors. Where does the coloring matter come from? Notice how delicately weathering will etch out the form of a fossil. What is the process?

DRAWER 136, ROCK WEATHERING: What illustrations of weathering do you find here? Explain the cavities in XIV; in I; in III.

DRAWER 137: Notice the effect of solution on the limestone specimens, I, III, VII and VIII. How can you account for the idges in I and II? What is the cause for the concentric shells 1 IV–VI? What do the specimens of chert illustrate as to eathering? What has happened in XIX? In specimen XX a series showing change from fresh rock to decayed product. hat has happened?

)RAWER 138, RESIDUAL SOIL: Specimens I–VI illustrate decay of granite. What changes do you detect? VII–XI trate a similar change in elaeolite syenite. XV is a residual of gneiss from Washington, D. C. XVI is a white lime rock Bermuda; it produces XVII, which is the insoluble residue ter weathering. What is the source of the reddish color? ine the other residual soils; XX is from feldspar.

DRAWER 139: Specimens I–III decay to form residual soils. IV is such a soil formed from limestone. Can you find in the soil any of the rock minerals? What changes do you notice?

MISCELLANEOUS PHENOMENA.

DRAWERS 140–141, GLACIATION (Tarr's Geology, 478–487; Brigham's Geology, 96–97 and 101; Scott's Geology, 110–115): How do you understand these scratches to have been made? Explain their irregularity in the specimens of Drawer 140. See also Drawer 131. What is boulder clay? Examine the larger specimens not in the laboratory. In 140–III, explain the variation in direction of scratches; also tell in 140–IV which way the ice moved, giving reasons. What is a slickenside (140–VIII)? How would you distinguish between a glaciated and a slickensided surface on a hand specimen?

DRAWER 142, CONSOLIDATION (Kemp's Handbook, 107; Tarr's Geology, 273–275): What modes of consolidation are illustrated here? Have you found any illustrations in previous drawers? Why is X flexible? *Do not break.*

DRAWERS 143–144, STRATIFICATION (Brigham's Geology, 215–216): What illustrations of stratification do you find? Why are fossils arranged as they are? Of what do the variations consist? How could you explain such variations in 144–XVIII?

DRAWERS 145–146, RAIN PRINTS, RIPPLE MARKS, ETC.: Examine each of these carefully. What caused 145–VIII? What is mud flow? Can you tell the direction of water movement in the ripples? Would they ever be formed in deep water? Examine 146–IX; which direction was the wind blowing when the rain prints were made?

DRAWER 147, CONE IN CONE, AND STYLOLITES: (Geikie, 316, 512): Examine these. The cause is not fully known.

DRAWER 148, GEODES: What is the origin of the cavities? What mineral is most common? Shake XXI to notice water. What does it signify? Explain the changes which have gone on in these specimens. In this connection examine the large coral (in the laboratory) from the same locality.

DRAWER 149, PETRIFIED WOOD AND STALACTITES: What is the nature of the process of petrifaction? What is the cause of the hole in the stalactites? How could stalactites ha-

impure and so irregular as XIV? What is the mineral in stalactites? Why arranged in rings? How are stalactites formed?

DRAWER 150, DENDRITES: What are these? How can they be distinguished from ferns?

DRAWER 151, REPLACEMENT, ETC.: Of what are shells made? What changes can you find in this drawer? What, for instance, in VI, VII, and VIII? What is shown in XVII? Where did the iron sulphide come from? Were the cavities there? What carried the iron sulphide?

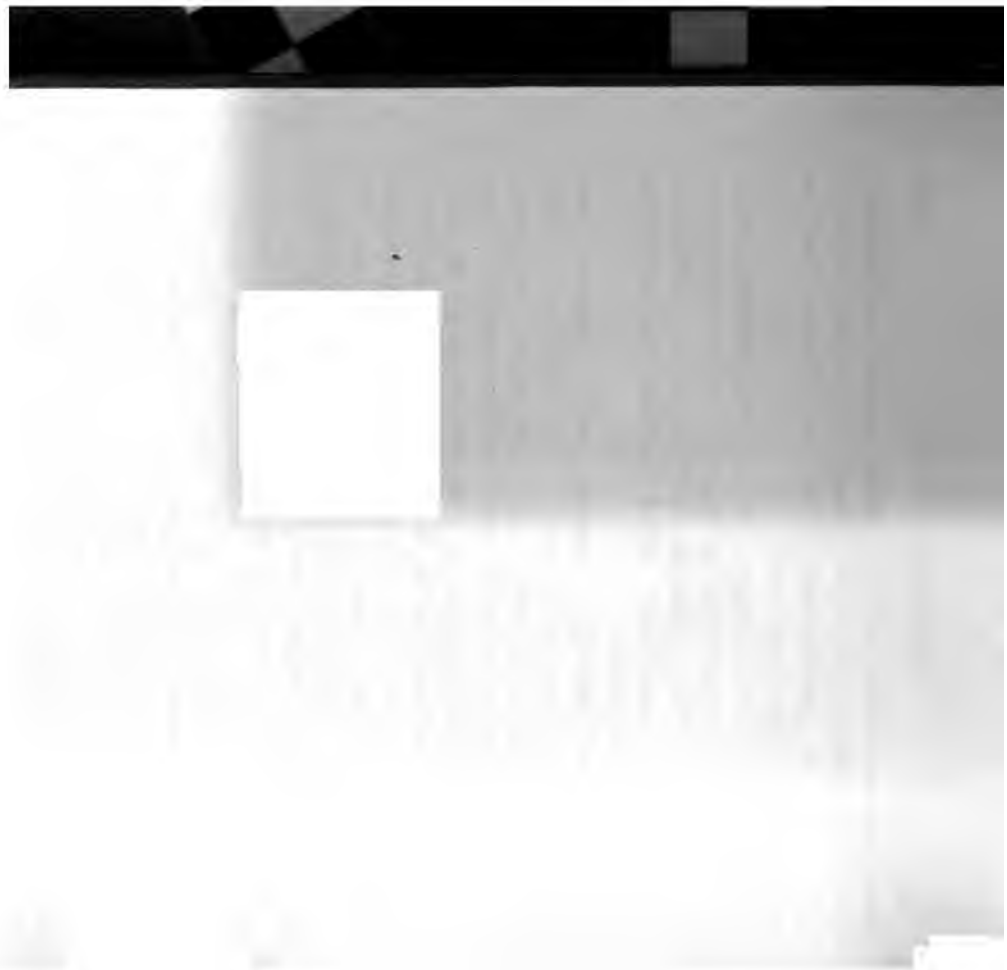
DRAWER 152, VEINS (Tarr's Geology, 380–382; Brigham's Geology, 85–87; Scott's Geology, 265–269): What are they? What causes the banding of some? Do you think the cracks previously existed, or were they made by the depositing minerals? Can you find any proof of your conclusion in the specimens? What is the difference between a dike and a vein in origin? In other respects? How could you tell them apart? What besides a vein is found in XVI? In XXVI one vein crosses another; which is the older? Find the same thing in another specimen. What is comb structure?

DRAWERS 153–161, FOSSILS (Introductory chapter on Historical Geology: Tarr's Geology; Brigham's Geology; Scott's Geology): Examine these specimens. What groups are represented? Which is represented by most specimens? What is a fossil? What illustrations are there of casts of some part of an animal? Of replacement? What are Brachiopods? Crinoids? What kinds of animals would be most likely to be handed down as fossils? Why are fern leaves often enclosed in nodules?

MAPS.

CONTOUR MAPS.

(Tarr's Elementary Physical Geography, 437–430): A study of a series of topographic maps to understand the meaning and significance of contours. Make a series of sections through parts of contour maps to show the surface features as expressed by the contours. What is a contour? What is contour interval? What is the difference between contour interval and scale? Sketch a small contour map of a hill 300 feet high, steep on one side; contour interval 20 feet. Make a sketch map of a gorge



cutting into a hill side; contour interval 20 feet; scale 1 mile to the inch; length of gorge 1½ miles; depth 115 feet; hill-side rising from contour 0 to 250 feet.

CONSTRUCTION OF GEOLOGIC SECTIONS FROM GEOLOGIC MAPS.

To construct these the class will be given a geologic map of some area and will be required to construct from it a section along a given line.

TERMS USED, (Tarr's Geology, 283-293): What are the following: outcrop; dip; strike; fold; fault; anticline; syncline; monocline; pitch; unconformity. Learn the first two columns of the Geological Time scale (page 86), and read, in Tarr's Geology pages 397–403.

EXPLANATION: A geologic map shows the areas of outcrop of the different beds. The number of formations appearing at the surface depends on the position of the beds and on the topography. In a region where the strata are horizontal, and the surface is flat, only one formation would appear at the surface, and a geologic map of such an area would show only one color. The underlying formations may be exposed either by erosion or by disturbances, such as folding or faulting of the rocks. In the case of erosion the lower beds of the section will be exposed in the bottoms of the deeper valleys, while the intermediate beds will outcrop on the valley sides. In such a map the colors representing the different formations show a serrated outline. Where the beds are exposed by folding, the formations often outcrop in the form of bands or curves.

CONSTRUCTION OF SECTION: In the first map the student may consider the surface as flat. In later ones the correct profile of the surface along the line of the section must first be constructed.

A section is constructed as follows:

(1) Lay off a line equal in length to the line on the map. If the page is not long enough, make two lines, one at the top of page, the other at the bottom.

(2) Beginning at one end, measure and mark off the width of each formation where it crosses the section line.

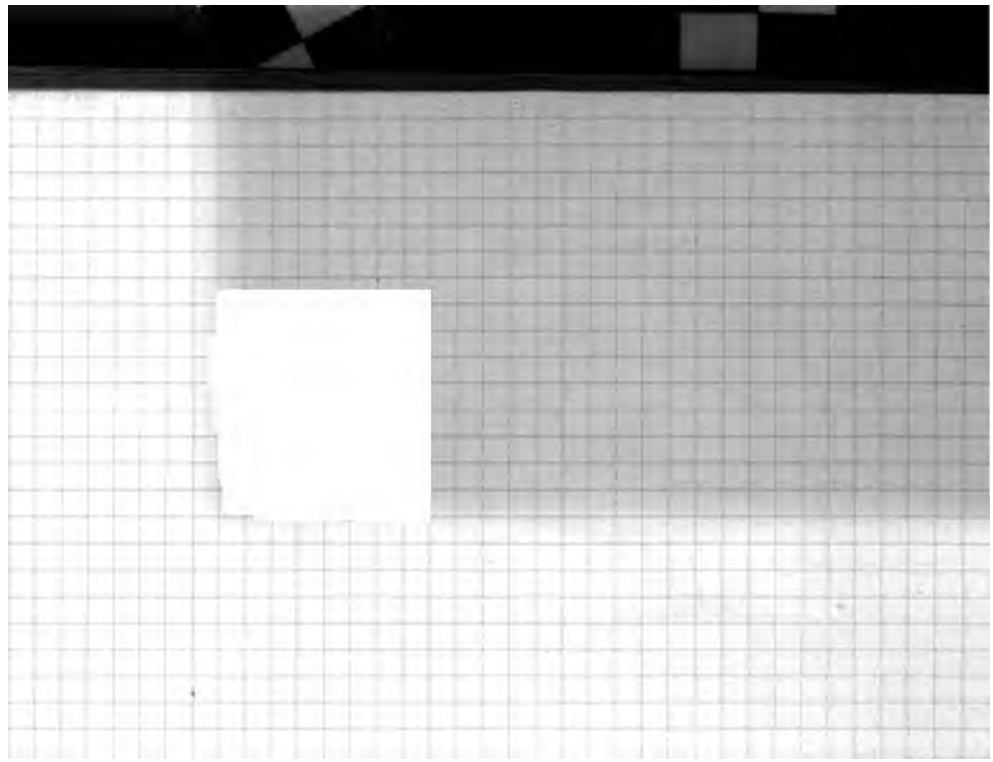
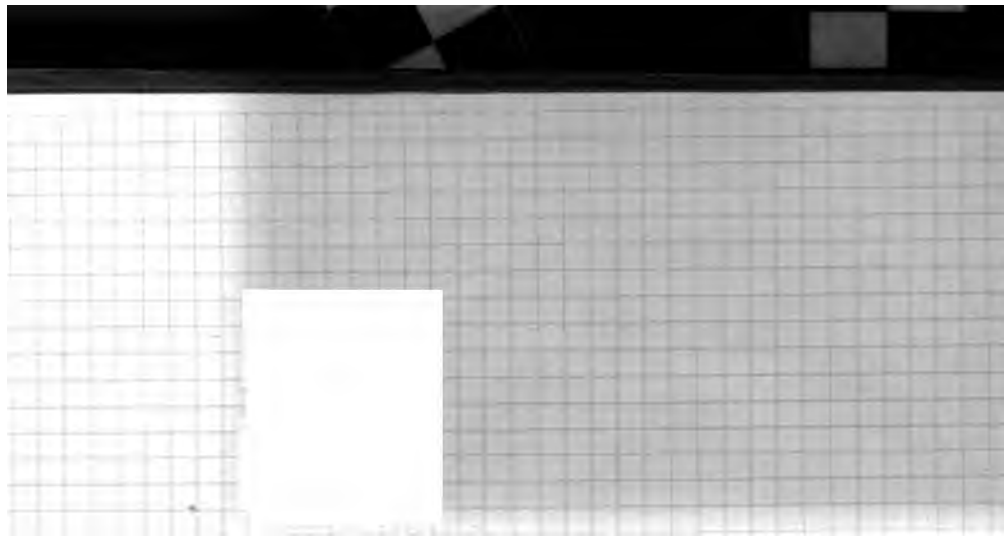
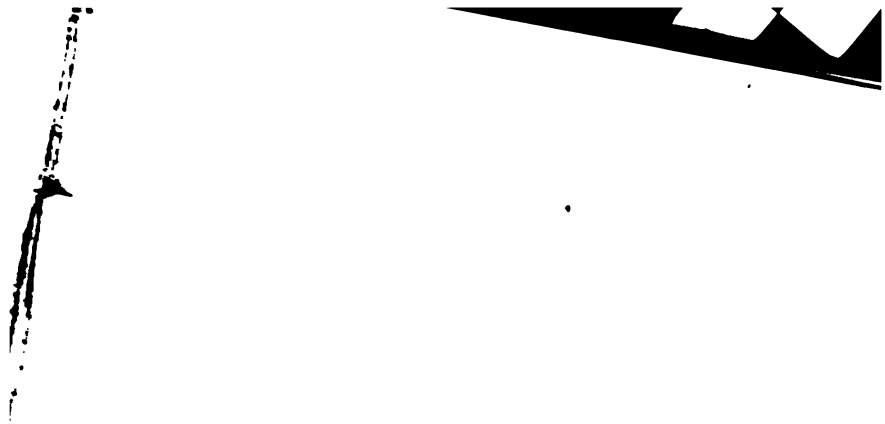
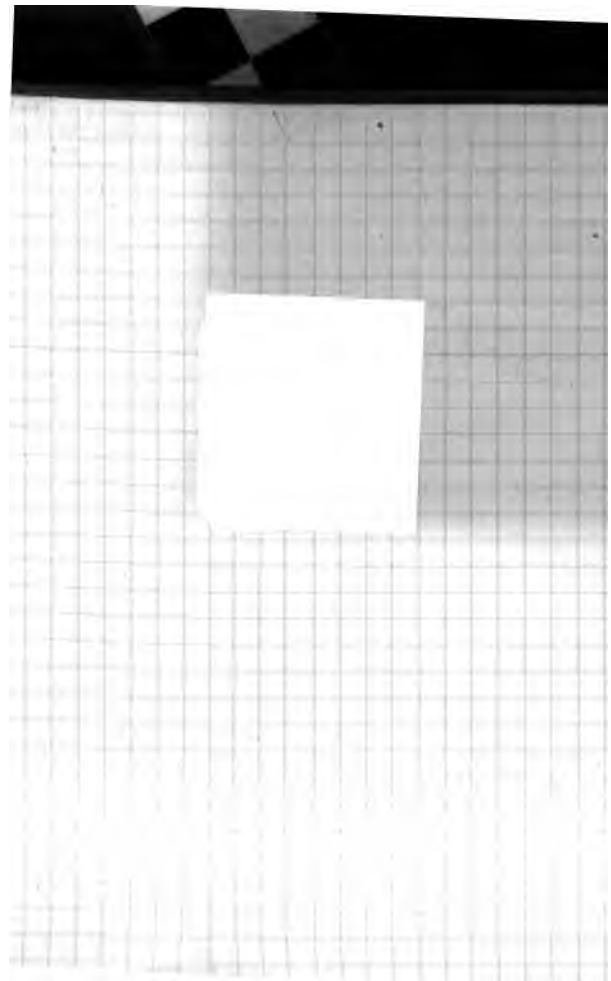
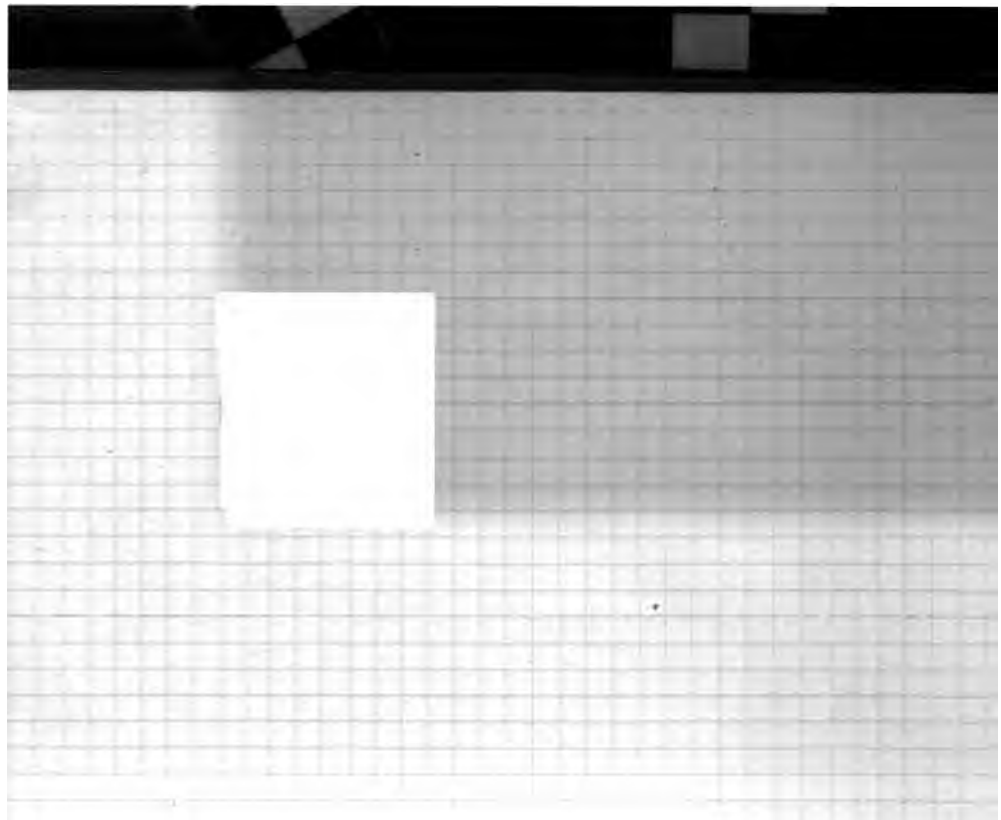
(3) Determine the direction of dip of each outcrop and indi-

(5) The presence of a fault line indicates a break in the structural relations, and the construction of the section must begin anew on the other side of the fault.

(6) Igneous rocks are intruded into the overlying rocks, or cut through them, forming dikes, flows, laccoliths, etc. Where the rock is of plutonic character it can usually be represented as a dike. If a volcanic neck it should be represented as such; a lava flow should appear as a surface flow in the section.

CONSTRUCTION OF GEOLOGIC SECTIONS FROM MODELS.

In addition to the map work, various sections will be drawn from the geological models in the laboratory until the student is able to read the geological structure from the colored models.

INTERPRETATION OF THE GEOLOGIC HISTORY OF AN AREA FROM A SERIES OF MAPS OR SECTIONS.

The student will be required to determine, as far as possible, from a study of the geologic maps and sections of some area, what changes have taken place in the past. This includes (1) conditions of sedimentation as shown by characteristics of rocks; (2) uplifts of land and erosion between any two periods of deposition; (3) presence of igneous